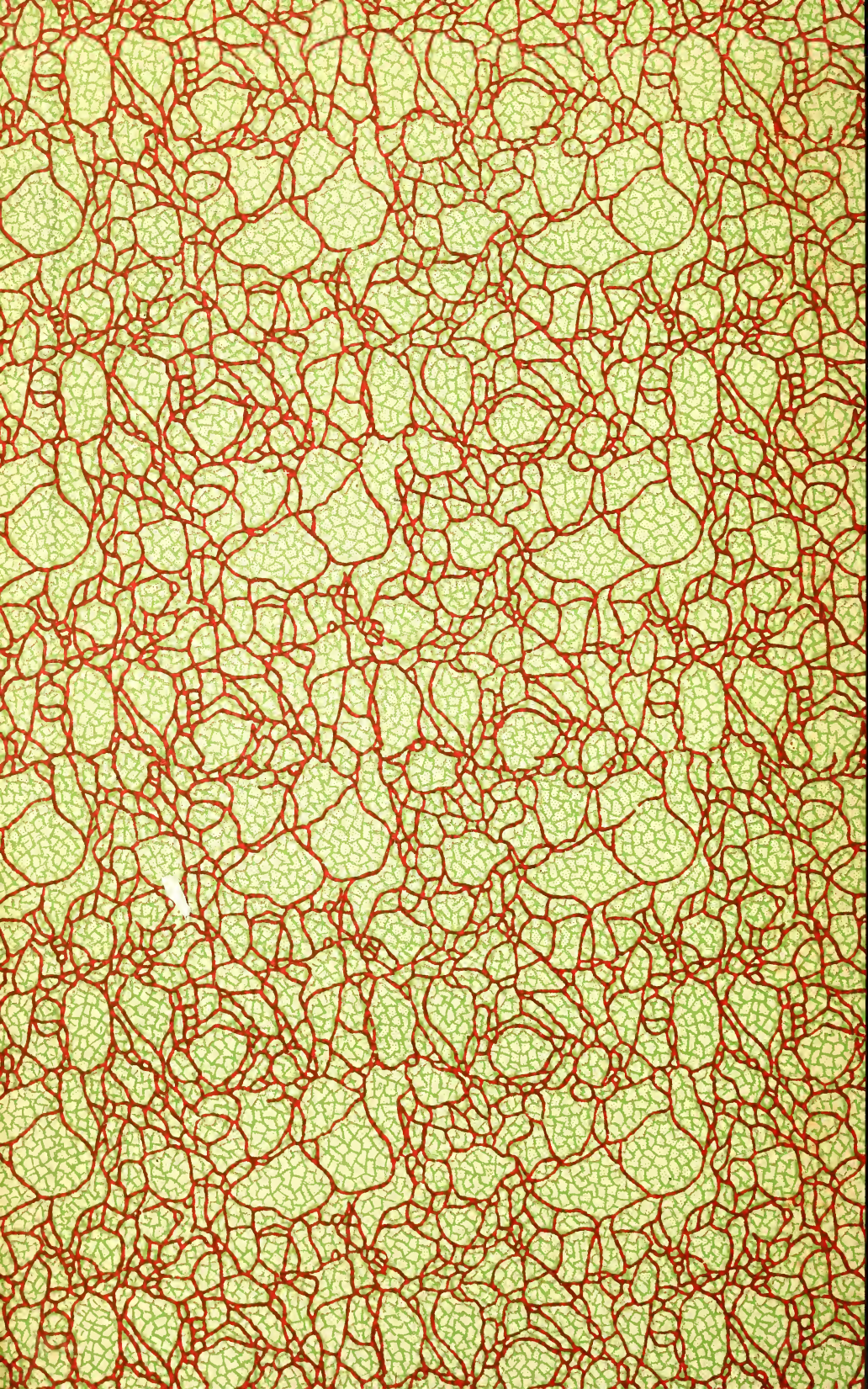
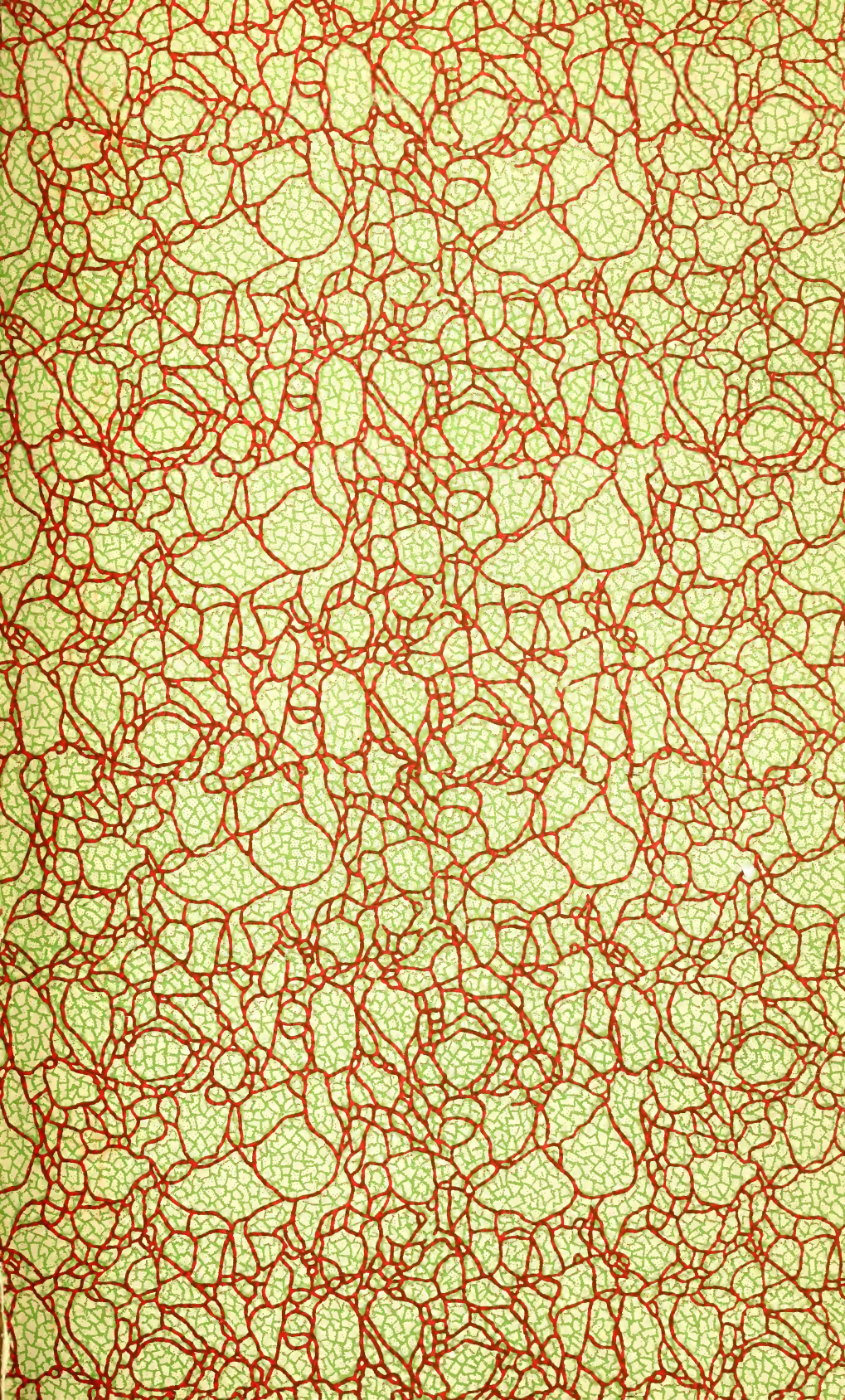








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PROCEEDINGS
OF THE
Forty-Third Annual Meeting

Indiana Academy
of Science

VOLUME 37
1927

J. J. DAVIS, Editor
S. A. CAIN, Assistant Editor

Held at Notre Dame University
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YEAR	PRESIDENT	SECRETARY	PRESS SECRETARY	TREASURER	EDITOR†
1886	Davis S. Jordan	Amos W. Butler		O. P. Jenkins	C. A. Waldo
1887	John M. Coulter	Amos W. Butler		O. P. Jenkins	C. A. Waldo
1888	*J. P. D. John	Amos W. Butler		O. P. Jenkins	G. W. Benton
1889	*John C. Brunner	Amos W. Butler		O. P. Jenkins	G. W. Benton
1890	*T. C. Mendenhall	Amos W. Butler		O. P. Jenkins	D. Bodine
1891	O. P. Hay	Amos W. Butler		O. P. Jenkins	D. Bodine
1892	*J. L. Campbell	Amos W. Butler		C. A. Waldo	W. J. Karslake
1893	J. C. Arthur	Amos W. Butler		C. A. Waldo	D. Bodine
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1895	A. W. Butler	John S. Wright		W. P. Shannon	E. G. Martin
1896	Stanley Coulter	John S. Wright		W. P. Shannon	A. L. Foley
1897	*Thomas Gray	John S. Wright		J. T. Scovell	L. B. McMullen
1898	*C. A. Waldo	John S. Wright	Geo. W. Benton	J. T. Scovell	H. L. Bruner
1899	*C. H. Eigenmann	John S. Wright	Geo. W. Benton	J. T. Scovell	H. L. Bruner
1900	*D. W. Dennis	John S. Wright	Geo. W. Benton	J. T. Scovell	L. J. Rettger
1901	*M. B. Thomas	John S. Wright	Geo. W. Benton	J. T. Scovell	C. C. Dean
1902	Harvey W. Wiley	John S. Wright	Geo. W. Benton	J. T. Scovell	H. E. Barnard
1903	W. S. Batchley	John S. Wright	G. A. Abbott	W. A. McBeth	H. E. Barnard
1904	C. L. Mees	John S. Wright	G. A. Abbott	W. A. McBeth	F. J. Breze
1905	John S. Wright	B. McMullen	G. A. Abbott	W. A. McBeth	F. Payne
1906	Robert Hassler	B. McMullen	Charles R. Clark	W. A. McBeth	J. J. Davis
1907	D. M. Mottier	B. McMullen	G. A. Abbott	W. A. McBeth	J. J. Davis
1908	*Glenn Culbertson	J. H. Ransom	G. A. Abbott	W. A. McBeth	J. J. Davis
1909	A. L. Foley	J. H. Ransom	G. A. Abbott	W. A. McBeth	J. J. Davis
1910	*P. N. Evans	Geo. W. Benton	J. W. Woodhams	W. J. Moonkhaus	J. J. Davis
1911	*C. R. Dryer	A. J. Bigney	Milo H. Stuart	W. J. Moonkhaus	
1912	L. P. Naylor	A. J. Bigney	F. B. Wade	W. J. Moonkhaus	
1913	*Donaldson Bodine	A. J. Bigney	F. B. Wade	W. A. Cogshall	
1914	Sovereign Burrage	A. J. Bigney	F. B. Wade	Wm. M. Blanchard	
1915	W. A. Cogshall	A. J. Bigney	F. B. Wade	Wm. M. Blanchard	
1916	A. J. Bigney	H. E. Enders	F. B. Wade	Wm. M. Blanchard	
1917	W. J. Moonkhaus	H. E. Enders	F. B. Wade	Wm. M. Blanchard	
1918	E. B. Williamson	H. E. Enders	F. B. Wade	Wm. M. Blanchard	
1919	E. B. Williamson	H. E. Enders	F. B. Wade	Wm. M. Blanchard	
†1920	H. L. Bruner	H. E. Enders	F. B. Wade	Wm. M. Blanchard	
1921	Howard E. Enders	Walter N. Hoss	F. B. Wade	Wm. M. Blanchard	
1922	F. M. Andrews	Walter N. Hoss	F. B. Wade	Wm. M. Blanchard	
1923	Charles A. Beltrons	Walter N. Hoss	H. F. Dietz	Wm. M. Blanchard	
1924	C. C. Dean	Flora Anderson	H. F. Dietz	Wm. M. Blanchard	
1925	E. R. Cummings	Flora Anderson	H. F. Dietz	Wm. M. Blanchard	
1926	W. M. Blanchard	R. C. Friesner	H. F. Dietz	C. M. Smith	
1927	Frank B. Wade	R. C. Friesner	H. F. Dietz	M. W. Lyon, Jr.	
1928	E. G. Mahin	R. C. Friesner	H. F. Dietz	M. W. Lyon, Jr.	

*Deceased.

†Officers continued—Annual meeting not held because of influenza epidemic.

‡Listed in year of Proceedings edited.

MINUTES OF THE SPRING MEETING.

NEW HARMONY, INDIANA.

The Indiana Academy of Science met for its regular spring meeting at New Harmony, Indiana, May 12-14, 1927. At a meeting held in Murphy Auditorium, Thursday, May 12, the Secretary was ordered to send telegram of condolence to Dr. Nieuwland, who was very ill at Notre Dame. Mr. George Taylor, President of the New Harmony Commercial Club, gave an address of welcome to the Academy and its members and presented a key of the city to President Wade. Further program of the evening consisted of addresses by Dr. Logan Esarey on "New Harmony Scientists," Miss Louise M. Husband on "Traditions and Monuments of New Harmony," and Dr. Amos Butler on "The Life and Contributions of Richard Dale Owen."

Dr. Butler announced that a copy of the original autographed list of charter members of the Academy had come into his possession and he suggested that photostat copies be made and the original be deposited in the State Library. Meeting adjourned.

Minutes of the Executive Committee. Friday noon, May 13, 1927. Dr. Butler moved that the President and Secretary act as a committee to procure photostat copies of the original signatures of the charter members of the Academy and to deposit original copy in the State Library. The committee was instructed to determine the best use of the photostat copies.

It was moved, seconded, and carried that Indiana House Bill No. 166, providing for adequate housing of the State Museum, State Library, and the Academy of Science Library be referred to the Committee on Relation of Academy to the State.

It was moved, seconded, and carried that the matter of state laws concerning archeological material be referred to the Committee on Archeology and that Mr. Montgomery be made a member of that committee.

The meeting was then adjourned.

Minutes of the Friday Evening Meeting. The Committee on Resolutions presented the following resolution which was unanimously adopted by a rising vote:

The Indiana Academy of Science at its meeting held in New Harmony desires to express its thanks and appreciation to the people of New Harmony; to Mr. Taylor for his words of welcome; to the Commercial Club, the ladies of the Methodist Episcopal Church, members of the Rebecca Lodge, ladies of the Episcopal Church or Guild; to the high school orchestra with Miss Helen Hovey as conductor; to the citizens for the use of their cars; to the Reception Committee; to Professor Esarey for his instructive address on "New Harmony Scientists"; to

Miss Louise M. Husband for her excellent address on "Traditions and Monuments of New Harmony"; to Mrs. Hale for the river trip given to our members; and to all others who have contributed to the success of our meeting which has been the most successful spring meeting the Academy has ever held. Therefore, it is moved that this expression of the great appreciation and thanks of the Academy be adopted and incorporated into the records of the meeting.

F. M. ANDREWS, Chairman.

Upon recommendation of the Membership Committee the following
58 applicants were accepted into membership in the Academy:

Brother Alphonsus, Notre Dame.
Benitz, William Logan, 724 Cedar St., Notre Dame.
Benning, Anthony F., Badin Hall, Notre Dame.
Burnett, Arthur, Paragon.
Ford, Miss Annie Birkbeck, Main St., New Harmony.
Buswell, Vernon L., East Washington St., Greencastle.
Cannon, Dominic J., University of Notre Dame, Notre Dame.
Carey, Lewis J., Lyons Hall, Notre Dame.
Cummins, Miss Margaret, Bloomington.
DeWulf, Emiel F., Notre Dame.
Flood, Sister Mary Aquinas, St. Mary's College, Notre Dame.
Florentine, Sister M., St. Mary's College, Notre Dame.
Foohey, William Logan, 1614 Forest Park, Ft. Wayne.
Gassensmith, Frederic M., Notre Dame.
Grass, Arthur M., 339B, N. E., Linton.
Greene, Robert L., Notre Dame.
Hafel, Clare Philip, Notre Dame.
Hanning, Flora, Evansville College, Evansville.
Hayward, James W., Notre Dame.
Hebert, Peter E., Notre Dame.
Heiser, Joseph Alan, Notre Dame.
Horan, Frank W., 914 Diamond Ave., South Bend.
Hoskins, John Hobart, Univ. Cincinnati, Cincinnati, Ohio.
Hull, Daniel, Univ. Notre Dame, Notre Dame.
Kaylor, J. F., Dept. Conservation, Indianapolis.
Kline, James Edward, Univ. Notre Dame, Notre Dame.
Lahr, John Paul, City Y. M. C. A., Indianapolis.
Lewis, Julia Lucile, 125 S. Sycamore St., Fairmount.
McKeon, Frederick T., Univ. Notre Dame, Notre Dame.
Mootz, Frank Joseph, 1958 Ashland Ave., Indianapolis.
Misselhorn, Richard Arthur, 229 Newman Ave., Kendallville.
Murch, Raymond Martin, Notre Dame.
Norris, Allen Anson, 208 N. Marion St., Elkhart.
O'Connell, Eugene Daniel, 725 Forest St., South Bend.
O'Hara, Francis J., Univ. Notre Dame, Notre Dame.
Perkins III, Samuel Elliott, 3251 N. Pennsylvania St., Indianapolis.
Pierce, Arthur Lester, Box 61, Univ. Notre Dame, Notre Dame.
Potter, Prilda H., 529 E. First St., Bloomington.
Rankin, Horace, R. F. D. 10, Bloomington.

Ransom, Clemie Ethel, 2202 N. Capitol Ave., Indianapolis.
Reynolds, J. J., Univ. Notre Dame, Notre Dame.
Rechenberg, Elizabeth Anna Marie, 805 Lincoln Ave., Valparaiso.
Relick, Betty R., 719 E. Corby St., South Bend.
Rockne, Knute K., Univ. Notre Dame, Notre Dame.
Schumacher, Rev. Matthew, Univ. Notre Dame, Notre Dame.
Shilts, Walter L., 714 E. Corby St., South Bend.
Simpson, Paul Freund, 1736 Hall Pl., Indianapolis.
Slavin, Arthur D., 2001 St. Paul St., Rochester, N. Y.
Snow, Charles Chapman, 315 Jackson St., Oakland City.
Spencer, Raymond C., Russellville.
Stratton, Everett F., Cambridge City.
Tumey, J. Iris, 330 Fowler Ave., West Lafayette.
Wenzke, Herman Henry, Univ. Notre Dame, Notre Dame.
Whitehead, Martha E., Main St., New Harmony.
Wible, Paul Gerald, Paoli.
Wilhelm, Ernest John, 1527 S. Michigan St., South Bend.
Wyatt, Mrs. Ima, 19 Norman Ave., Evansville.
Yang, Peter S., Box 85, Notre Dame.

Professor Bigney invited members and their friends to visit Evansville College on their way back home.

The Secretary was ordered to send greetings to Dr. C. W. Hargitt of Syracuse, New York.

Dr. M. W. Lyon, Jr., presented the following resolution concerning zoological nomenclature:

WHEREAS, Dr. Franz Poche of Vienna, Austria, has submitted certain well-known propositions relative to zoological nomenclature to the International Commission on Zoological Nomenclature and plans to bring these propositions before the International Zoological Congress to be held in Budapest, 1927, in case these propositions are not unanimously recommended to the Congress by the Commission; and,

WHEREAS, The zoologists of the Indiana Academy of Science feel that the adoption of the proposition unless unanimously recommended by the Commission to the Congress will result in greater confusion in zoological nomenclature than now exists; and,

WHEREAS, The zoologists of the Indiana Academy of Science feel that all questions of zoological nomenclature can be more justly determined and amicably settled by a representative and relatively stable International Commission of persons especially interested and trained in zoological nomenclature than by a congress whose personnel changes from meeting to meeting and is determined in large part by the country in which the Congress is held, and which has interests of wider scope than technical nomenclature; therefore, be it

RESOLVED, That on the recommendation of its zoologists the Indiana Academy of Science assembled at the Spring Meeting of the Academy, at New Harmony, Indiana, 1927, deplore any attempt or attempts to change the status of the International Rules of Zoological Nomenclature

unless unanimously recommended by the International Commission or to allow the International Zoological Congress to settle questions of nomenclature that have not been submitted to such Congress by the unanimous approval of the International Commission; and be it further

RESOLVED, That these resolutions be spread upon the minutes and a copy sent to the Secretary of the International Commission on Zoological Nomenclature.

The above report was adopted by the Academy and ordered spread upon the minutes and a copy sent to Dr. C. W. Stiles.

The meeting was now turned over to the toastmaster, Dr. Amos Butler.

Greetings were read from Dr. Harvey W. Wiley and from Dr. David Starr Jordan. Dr. A. L. Foley was called upon to speak briefly of Dr. Eigenmann, deceased. Prof. A. J. Bigney spoke similarly concerning Professor Culbertson, and Professor Rettger spoke concerning Dr. Charles R. Dryer. The Secretary was ordered to send the condolences of the Academy to the families of these former distinguished members, all past presidents.

Mrs. Charles Brossman read from the diary of Thomas Dean. Mrs. Caroline Parks Dale Mediger spoke of the home of Robert Owen, and Mr. Harry Dietz spoke of Thomas Say, the first great American entomologist.

One hundred fifty members of the Academy were registered for these meetings. One hundred forty-three attended the noon dinner and 160 were present at the evening dinner.

Meeting adjourned.

RAY C. FRIESNER, Secretary.

WINTER MEETING.

PROGRAM OF THE FORTY-THIRD ANNUAL MEETING OF
THE INDIANA ACADEMY OF SCIENCE
HELD AT

UNIVERSITY OF NOTRE DAME
NOTRE DAME, INDIANA
December 1, 2, and 3, 1927

THURSDAY, DECEMBER 1, 1927.

- 10:00 a. m. Meeting of Entomologists of Indiana.
6:00 p. m. Executive Committee Dinner, Oliver Hotel, South Bend.
8:00 p. m. Annual Meeting of Executive Committee.
Reports of Officers and Committees.

FRIDAY, DECEMBER 2, 1927

- 9:00 a. m. General Session.
General Business Session.
Address of Welcome, Rev. Matthew J. Walsh, C. S. C.,
President of the University of Notre Dame.
Response, Frank B. Wade, President of the Indiana Academy
of Science.

In Memoriam—

- Theodore Allebach.....By M. G. Mellon
Wm. T. Baker.....By R. C. Friesner
Elias Chansler.....By Walter Chansler
W. P. Crockett.....By Frank B. Wade
Glenn Culbertson.....By Wm. A. Millis
Charles R. Dryer.....By L. J. Rettger
Carl H. Eigenmann.....By F. Payne
Charles W. Hargitt.....By A. J. Bigney
Claude H. Harshbarger.....By Paul Weatherwax

Presentation of Papers of General Interest.

- *A Botanist in Jamaica.....M. S. Markle
The European Starling in America.....Amos W. Butler
Aerial Photography in Indiana.....T. M. Bushnell
Perverted Benevolence as an Influence upon Racial
Development Gerard Fowke
*Ancient Cities of Northwestern Arizona....A. S. Reagan
A Plea for John Kissinger.....R. A. Gantz

12:00 noon. Academy Luncheon.

1:30 p. m. Sectional Meetings.

* Papers starred not published in this Proceedings.

BACTERIOLOGY, PHYSIOLOGY AND HYGIENE.

CHARLES H. BEHRENS, Chairman.

- Agglutinin Production: Total Amount Injected Varied,
Dosage and Frequency of Injections Constant...
.....Charles H. Behrens
- Preservation of Isohemagglutinating Serum with
Phenolized Glycerol.....M. W. Lyon, Jr.
- Antaeus—Contact with the Soil.....Robert Hessler
- *A Study of *Pseudomonas aeruginosa*....G. W. Albertson
- The Longevity and Swimming Ability of Spermatozoa
.....Benjamin H. Grave and R. C. Downing
- A Study of School Room Ventilation, Involving a
Comparison of Two Types of Heating and Venti-
lating Plants
.....R. A. Gantz and Harriet Thornbill Phipers

BOTANY.

F. M. ANDREWS, Chairman.

- Recent Indiana Weeds—1927.....Albert A. Hansen
- Notes on the Technique of Plant Mounting.....
.....J. A. Nieuwland and A. D. Slavin
- Plants New or Rare in Indiana—XIV....Chas. C. Deam
- Monstrosities in *Trillium*.....F. M. Andrews
- Observations on the Teratology of the Genus *Cuscuta*
.....T. G. Yuncker
- *A Floristic Study of the Trees of the Dune Region
of Northern Indiana.....Henry C. Cowles
- *The Ecology of the Mosses and Liverworts at Turkey
Run.....Carolyn H. Swanson
- Holdfast Cells in *Spirogyra*.....Freda Doris Reed
- Plant Diseases in a Home Garden.....E. B. Mains
- Mycorrhiza Bearing Species in the Vicinity of La-
fayette, Indiana.....K. D. Doak
- Indiana Fungi—X.....J. M. Van Hook
- Structure of Some Carboniferous Plants from Illinois
.....J. Hobart Hoskins
- The Ferns of Turkey Run.....Otto Behrens, Jr.
- New Yellows Resistant Varieties of Cabbage in In-
diana.....C. T. Gregory
- Ecological Relationship of Fungi in Cultures.....
.....C. L. Porter
- Hydrogen Ion Studies of Water, Peat, and Soil, in
Relation to Ecological Problems at Bacon's
Swamp, Marion County, Indiana....Stanley A. Cain
- The Bog Clearweed, *Adicea fontana* Lunell, in In-
diana.....M. W. Lyon, Jr.

* Papers starred not published in this Proceedings.

- *Identification Key to the Weeds of Indiana.....
Albert A. Hansen and F. J. Pipal
 The Relation of Lime to the Absorption of Iron by
 Plants.....W. P. Allyn
 Modified Narcissus Flowers.....F. M. Andrews
 *Plant Tissue in an Indiana Coal Ball..Fredda Doris Reed
 Observations Concerning Clover Diseases....E. B. Mains
 Controlling Tomato Leaf Mold in Greenhouses in In-
 diana.....C. T. Gregory
 Excess Soluble Salts as the Cause of Vegetable Dis-
 eases in Greenhouses.....
C. T. Gregory and S. D. Conner
 Deposition of Material by Water Plants...F. M. Andrews
 A Study of Lichens.....F. M. Andrews
 Some Flowering Plants of Monroe County, Indiana
F. M. Andrews

CHEMISTRY—MATHEMATICS—PHYSICS

WM. M. BLANCHARD, Chairman

- The Rôle of Valence and Electrons in the Teaching of
 General Chemistry.....Wm. M. Blanchard
 A Method of Studying the Form and Intensity of an
 Explosive Sound Wave.....Darrell B. Green
 *Catalysis in Acetylene Reactions.....J. A. Nieuwland
 Some Atmospheric Electric Potential-Gradient Meas-
 urements.....James F. Mackell
 Induction and Radiation.....R. R. Ramsay
 Making Bibliographies More Useful.....M. G. Mellon
 Mechanism of a Condensed Electric Spark Discharge
H. A. Zinzer
 *X-Ray Analysis of the Structure of Potassium Nitrate by
 Laue Spots.....Eugene D. O'Connell
 Velocity of Sound in Free Air.....Arthur L. Foley
 Thermal Conductivity of Condensing Vapor Films...
Herman H. Wenzke
 The Calibration of Radio Frequency Galvanometers
 and Milli-Ammeters.....J. B. Hershman
 The Validity and Interpretation of Mathematical
 Formulas.....Will E. Edington
 Food Fakes and Fancies.....R. H. Carr
 *The Verification of the Lommel Diffraction Theory in
 Light¹ Mason E. Hufford
 Three Electrodes Vacuum Tube Oscillator, a Special
 Case of Parallel Resonance.....Eung Tyun Cho
 A Magnetic Method for the Determination of the
 Elastic Limit of Iron and Steel.....B. A. Howlett

¹ To be published in the Physics Review.

* Papers starred not published in this Proceedings.

- An Efficient Stirrer for Gas Absorption.... A. F. Benning
 Notes on the Lines of Force in a Plane Electrostatic
 Field Containing Two Charges..... C. K. Robbins
 Energy Losses in Railroad Track Hammers.....
 Edwin Morrison
 Two New Navigation Instruments..... W. A. Cogshall
 Some Observations on the Properties of Certain So-
 Called Thermal Insulators..... John B. Dutcher
 *Description of Soil Colors by the Factorial System
 J. Gladden Hutton
 Some Properties of Pin-hole Sound Probes.....
 James E. Brock
 *Synchronizing A. C. Motors²..... J. A. Caparo
 Case-Carburization in Presence of Ferrosilicon.....
 R. C. Spencer and E. G. Mahin
 *Curved and Reflex Exponential Horns..... A. L. Foley
 The Analysis of Electrolytically Deposited Lead Per-
 oxide by the Method of Lux.....
 M. G. Mellon, W. F. Reed and H. F. Wilkins
 A Calorimetric Determination of Core Losses in High
 Frequency Transformers..... B. A. Howlett
 *Vector Diagram for the Compensation of Lagging
 Currents by Means of the Synchronous Condenser
 J. A. Caparo
 The Diffusion of Hydrogen in Iron..... E. G. Mahin
 *The Diaphonic Trumpet Horn..... Arthur L. Foley
 Scattering of Light by Small Particles... Edwin Morrison
 *Pressure-Depth Apparatus..... Edwin Morrison
 *The Trisection of Angles..... C. S. Banworth
 Colloidal Arsenic Trioxide in the Arsenic Determina-
 tion..... E. G. Mahin and A. F. Doyle
 The Aurora Borealis..... E. A. Smith

GEOLOGY—GEOGRAPHY—ARCHEOLOGY

FRED J. BREEZE, Chairman

- Nature Guiding at Turkey Run State Park.....
 Sidney R. Esten
 *Petrographical Note on Indiana Glaciation.....
 Frank B. Wade
 Theory of Thunderstorms..... Daniel Hull
 *The Tertiary-Pleistocen of the Navajo Country, Ari-
 zona, with a Description of Some of Its In-
 cluded Fossils..... Albert B. Reagan
 The Distribution of Precipitation in Relation to the
 Mississippi Basin Flood of 1927..... J. E. Switzer
 Geography of Indiana Agriculture..... S. S. Visser

² To be published in Power Plant Engineering.

* Papers starred not published in this Proceedings.

- *Composite Maps³.....B. H. Schockel
 Further Observations on the Erosion of Clifty and
 Butler Ravines, Jefferson County, Indiana.....
J. Archer Culbertson
 Some Interesting Physiographic Features of the Up-
 per Wabash Drainage Basin in Indiana.....
Robert R. Shrock
 *Patton Cave—A Type Associated with Fault Struc-
 ture.....Arch R. Addington
 Physiography of the Kankakee Region.....
T. M. Bushnell
 *The Springport Esker.....Fred J. Breeze
 Archeological Investigations in Greene County.....
W. N. Logan
 Copper Nugget Found at Turkey Run...Sidney R. Esten
 Notes on Some Ohio River Terraces.....
J. Archer Culbertson
 The Litten Natural Bridges and Closely Associated
 Phenomena, Eastern Owen County, Indiana.....
Arch D. Addington
 *Village Population in Indiana.....Fred J. Breeze
 An Analysis of Erosion.....Clyde A. Malott

ZOOLOGY

AMOS W. BUTLER, Chairman

- *Snakes of Indiana.....A. Lester Pierce
 Insects of Indiana for 1927.....J. J. Davis
 *Identical Twin Embryos of the Chick Blastoderm....
L. J. Rettger
 *The Sexual Cycle of Pulmonate Snails...C. P. Hickman
 Notes on Birds of Lake Maxinkuckee Region.....
S. E. Perkins III
 *Bird Records, 1927.....Brother Alphonsus
 *Pigmentation in Goldfish.....Walter N. Hess
 The Starling in Madison County, Indiana.....
Mrs. Louise S. Swain
 Some Interesting Indiana Bird Records.. Amos W. Butler
 *An Annotated List of the Lizards of Lee's Ferry,
 Arizona.....Stewart Springer
 Summer Resident Birds of Turkey Run State Park
Frederick H. Test
 The Occurrence of the European Starling at West
 Lafayette, Indiana.....
Louis A. Test and Frederick H. Test
 Records of Blueberry Insects in Indiana.....K. D. Doak
 Nesting of the Sycamore Warbler.....Amos W. Butler

³ To be published in Journal of Geography.

* Papers starred not published in this Proceedings.

- A List of Reptiles and Amphibians Taken in Marion
County, Indiana, in 1924-27.....Stewart Springer
*Rythms in Protozoa in Activated Sludge.....
.....Stewart Springer

6:00 p. m. Annual Academy Dinner.

President's Address—"More Scientific Education; Less Educational Measurement." Frank B. Wade.

7:30 p. m. Complimentary Concert—University of Notre Dame Glee Club, Mr. Joseph J. Casasanta, Director.

8:15 p. m. Public Lecture, "Nature and Man in Abyssinia", by Dr. Wilfred H. Osgood, Curator of Zoology, Field Museum of Natural History, Chicago, Illinois.

SATURDAY, DECEMBER 3, 1927.

9:00 a. m. Inspection trips to many points of interest.

MINUTES OF THE EXECUTIVE COMMITTEE.

DECEMBER 1, 1927.

The Executive Committee was called to order by President Wade at 8:00 p. m. in the Oliver Hotel. The following members of the committee were present: F. M. Andrews, C. A. Behrens, W. M. Blanchard, Amos W. Butler, W. A. Cogshall, Stanley Coulter, J. J. Davis, C. C. Deam, H. F. Dietz, H. E. Enders, A. L. Foley, R. C. Friesner, W. P. Morgan, D. M. Mottier, L. J. Rettger, E. B. Williamson, J. S. Wright, F. B. Wade, F. J. Breeze, M. W. Lyon, Jr.

Minutes of the New Harmony meeting were read and approved.

The Committee appointed at the New Harmony meeting to take action regarding photostating charter member signatures reported progress and asked for further instructions. Pursuant thereto a motion was passed requesting that the names of the charter members of the Academy be reproduced in their own handwriting, the same to appear in the next volume of the Proceedings and reprints of the same to be sent to the various libraries of the State.

Reports of officers followed:

Academy Foundation.—Chairman Butler gave the following report:

December 1, 1927, balance on hand.....	\$81 06
Total receipts, including cash for one U. S. L. L. Bond.....	328 34
Total	\$409 40
Investments made during the year.....	400 00
Balance on hand December 1, 1927.....	\$9 40

* Papers starred not published in this Proceedings.

ASSETS.

U. S. 4th L. L. Bond.....	\$50 00
Muncie Masonic Temple, Preferred.....	200 00
Railroadmen's Building and Savings Association.....	1,300 00
Balance shown above.....	9 40

Total Assets\$1,559 40

President Wade read a letter from Mr. John S. Wright who made a contribution of \$100 to the Academy Foundation. The President and Secretary were instructed to express to Mr. Wright the appreciation of the Executive Committee for his splendid contribution.

Archeological Survey.—Chairman Logan reported that “a field party under the direction of the chairman of the committee excavated the Hamlin Mound and the Baker-Lowe Mound. These mounds are located in Greene County near Worthington. Thirteen burials were found in two horizons in the Hamlin Mound and nine burials were found in the Baker-Lowe Mound. These mounds yielded skeletal materials, pottery, beads, arrow points, awls, axes, hammers, spear points, celts and other artifacts. A report has been prepared for publication in the Proceedings of the Academy.”

Auditing Committee.—Chairman Behrens reported that the books of both the Treasurer and the Editor had been audited and found to be correct.

Biological Survey.—Chairman Dietz reported considerable activity of a survey nature as evidenced by the number of titles appearing in the Proceedings of the Academy for 1926, and on the present program for 1927. In addition there appeared during the year a “List of the Ferns and Flowering Plants of the Dunes State Park” in the American Midland Naturalist, by Dr. M. W. Lyon, Jr. Chairman Dietz outlined plans for co-ordinating and organizing this work amongst other workers of the state and recommended that “members of the Academy who are interested in the following groups of life take steps to prepare articles covering them for the State following the general style of Deam’s Trees and Shrubs of Indiana and Evermann and Clark’s Fishes of Lake Maxinkuckee: Mammals, Birds, Reptiles, Amphibians, Fishes, all orders of Insects and Molluscs.

The committee further recommended, “that Deam continue his work on the flowering plants and ferns. Works on the mosses and liverworts and larger fungi are also needed. The Committee feels that the Academy should advocate a research collection of specimens for study, collected from Indiana, such collection to be centrally located at one of the state universities or at Indianapolis. The Committee also feels that the biological science departments of the high schools of the State could be made to serve in a very useful way if they would maintain a well labeled study collection of the plants and animals of the immediate vicinity in which they are located.

"Early in 1928 the membership of the Academy will receive a questionnaire asking in what field of biological science he is working and its relation to biological survey. It is hoped that each and every member, whether he is a biologist or not, will promptly return this questionnaire."

Editor.—J. J. Davis reported as follows:

Volume 36 of the Proceedings of the Indiana Academy of Science was distributed Sept. 12, 1927. The usual delays in printing were encountered. The cost of the Proceedings for the past four years was as follows:

	1923	1924	1925	1926
Cost.....	\$1,282.18	\$1,668.64	\$1,404.80	\$1,402.91
Number of copies.....	1,000	1,300	1,300	1,300
Number of pages.....	336	428	393	364
Number of cuts.....	74	107	61	69
Kind of binding.....	Paper	Cloth	Cloth	Cloth

The financial report, not including clerical help and other editorial expenses, as follows:

STATE FUNDS.

Annual Appropriation for 1926 Proceedings.....	\$1,200 00
Cost of 1926 Proceedings.....	\$1,402 91
Balance due, paid from reprint fund.....	202 91
	\$1,402 91

REPRINT ACCOUNT.¹

Balance from 1925 account.....	\$114 85
Received from authors for reprints.....	222 85
	\$337 70
Paid Burford for extra reprints.....	\$106 25
Paid Burford for extra cost of Proceedings.....	202 91
Express, postage, etc., on cuts, reprints, manuscripts, proof, etc., not charged elsewhere.....	15 30
Lettering map	75
Photograph	75
	\$325 96
	\$325 96
Balance	\$11 74
Due on reprints.....	40 15
Total Assets	\$51 89

The next Proceedings will be better supported inasmuch as the last Legislature appropriated \$1,500 in lieu of the present annual appropriation of \$1,200. This increased amount with the small fees received for reprints should enable us to publish a larger volume and include more of the papers submitted than formerly.

¹ A charge is made for reprints to add to the available publishing fund.

Membership.—Chairman Enders announced that at present he had 40 applications for membership in the Academy. Reading of these was deferred until a later meeting. Special mention was made of the activity of Dr. Mahin and Dr. Lyon and others of Notre Dame and South Bend in securing over 40 names for new members from this part of the State during the present year. (Most of these were admitted to membership at the Spring Meeting.)

Press Secretary.—H. F. Dietz, Press Secretary, called attention to the excellent assistance given him by Father Nieuwland, who was elected Assistant Press Secretary at the last annual meeting. Proper publicity for the present meeting was obtained by working through the Department of Journalism of the University of Notre Dame with Dr. Nieuwland and Dr. Mahin supplying the news stories and the Press Secretary augmenting these stories through the press associations at Indianapolis. This plan, due almost entirely to the co-operation that has been accorded the Press Secretary, has been very successful. The Press has always been very generous with the space given to Academy publicity and the Press Secretary, through the clipping service of the Department of Conservation, has found that the stories of both the Spring and the Annual Meetings are widely used by the newspapers. Again it is worth while to mention that members of the Academy should send brief abstracts of their papers to the Press Secretary, since he is continually being asked for publicity statements concerning papers on the program.

Program Committee.—Chairman Mahin presented the program of meetings and papers for Friday. He emphasized the necessity of promptness in beginning all meetings. He announced a special meeting of systematic botanists for Saturday morning. Special trips to manufacturing plants were also announced.

Relation of Academy to State.—Dr. Logan made a brief report in the absence of Chairman Wallace. He called attention to the need of action if a museum building to be built on the Memorial Plaza at Indianapolis is to be proposed. The following resolution was presented:

"Whereas, under the present crowded conditions of the Indiana State Capitol, there is not adequate space for displaying the valuable collections of historical, archeological, and natural science objects now in charge of the Department of Conservation:

And whereas, the great value of these exhibits to visual and scientific education is generally recognized in practically all other states; and since it is well known that Indiana is losing important collections yearly because of inadequate space for exhibition:

Therefore be it resolved, that the members of the Indiana Academy of Science in session assembled, do hereby petition your honorable body to give careful consideration to the matter of providing an adequate building on the World War Memorial Plaza for the purpose of properly exhibiting the collections above mentioned."

Research Committee.—Chairman Foley reported that circular letters had been sent to over 500 of the larger and more important industrial

concerns of the State emphasizing the research service of the Academy in solving specific problems which confront manufacturers and also stressing the memorial idea in calling attention to the fact that the money usually spent in marble or similar memorials would really provide a very much more enduring memorial and at the same time a blessing to mankind if it were used to establish fellowships or endow scientific laboratories.

State Library Committee.—Chairman Dietz called attention to the very crowded condition of the State Library and noted that under the conditions the Academy Library was receiving a generous treatment at the hands of the State Librarian. He urged that the Academy use all of its resources to aid in securing a new state library building. A motion was presented by Mr. Dietz that a committee be appointed to draw up a resolution stating the Academy's interest in securing a new library building. Doctors Logan and Malott were appointed to draw up this resolution.

Treasurer.—Treasurer Lyon recommended that statements for dues be sent out in the same envelope with preliminary announcements of Winter Meetings and that stamped, window type envelopes be used. He presented the following report:

Received from predecessor, March 4, 1927.....	\$693 00
Collected from dues to November 30, 1927.....	427 00
Donations from individuals and corporations for expense of annual meeting	100 00
Endowment Fund from John S. Wright.....	100 00
American Association for Advancement of Science.....	90 50
	\$1,410 50

DISBURSEMENTS.

Postage for notices, programs, proceedings, correspondence...	\$172 02
Editor for 1924, 1925 Proceedings.....	99 25
Printing, programs, notices, tickets, etc.....	45 75
Stationery (for two years).....	109 10
Ledger cards and filing case for Treasurer.....	14 35
Addressograph stencils	8 92
Clerical expenses, Secretary and Treasurer.....	9 67
	\$459 06
Balance on hand.....	951 44
	\$1,410 50

Treasurer Lyon recommended that \$200 be set aside from the general fund of the Academy to be added to the research fund. This is in addition to the \$100 contributed by Mr. John S. Wright and the \$100 received from the American Association for the Advancement of Science.

New Business.—Chairman Mahin of the Program Committee recommended that at least one member of the Program Committee and the

Membership Committee be continued upon the same committees for the following year. This was seconded and adopted.

J. J. Davis made the following recommendation for amendment to Section 3 of Article II of the Academy Constitution:

"Nominations for Fellows and Honorary members of the Academy shall be made to the chairman of the Nomination Committee previous to the annual meeting of the Executive Committee. The Nomination Committee shall submit their recommendation to the Executive Committee, which shall then pass the nominees on to the general session of the Academy for final approval."

Dr. Lyon recommended that all names of members of the Academy be listed in one membership list with proper designation as to class of membership. The motion was seconded and passed.

E. B. Williamson moved that the Academy recommend that Dean Coulter be reappointed by the Governor to the Conservation Commission of the State upon the expiration of Dean Coulter's present term. This was seconded and unanimously carried.

Dean Coulter moved that Dr. Amos Butler be recommended to the Academy for the honor of "Honorary Member." This motion was unanimously carried.

The invitation of Sigma Xi to hold the next winter meeting of the Academy at Indiana University was accepted with thanks.

Chairman Coulter of the Nominations Committee recommended the following members for Fellows:

Robert Ridgway, Olney, Illinois.

C. L. Mees, Rose Polytechnic Institute, Terre Haute.

A. C. Kinsey, Indiana University, Bloomington.

Richard Lieber, Department of Conservation, Indianapolis.

W. E. Edington, Purdue University, West Lafayette.

This report was accepted and referred for final action to the General Session.

It was moved, seconded, and carried that Butler and Jordan's paper on New Harmony, which appeared during the summer, be reprinted in the 1927 Proceedings of the Academy.

Meeting adjourned at 10:00 p. m.

MINUTES OF THE GENERAL SESSION.

DECEMBER 2, 1927.

Minutes of the Executive Committee were read and approved.

Recommendation regarding reappointment of Dean Coulter to the Conservation Commission was unanimously carried by the membership present.

Amendments to Constitution offered during the meeting of the Executive Committee were approved and ordered to become a part of the Constitution of the Academy.

Recommendations of the Nominating Committee for Fellows were approved and the Secretary instructed to cast ballot for same.

Motion of Dean Coulter nominating Dr. Amos Butler to honorary fellow, made to the Executive Committee, was approved unanimously.

The following resolution was presented by Chairman Andrews of the Resolutions Committee and adopted by the Academy:

WHEREAS, Librarians and others are caused unnecessary work and confusion when they catalog book reviews and often short articles in magazines and books where the author or reviewer signs only his initial as author.

WHEREAS, The reader is deprived of the knowledge of the author, which is a source of disappointment; whereas, publishers of meritorious books are deprived of the benefits resulting from a favorable review by a well-known author; and, whereas, the reader may often be better guided in his purchases.

WHEREAS, A book review should not be regarded as complete unless the size, style of binding, number of pages, illustrations, figures, maps, and price are given (if the price does not include delivery, the weight of the book should be added so that purchasers may accompany order for book with check for correct amount and thus avoid unnecessary correspondence).

WHEREAS, It is often the case where the transactions of societies and the like are often published and distributed without bindings, which unfits them for library purposes and which delays their circulation and adds two to five times their cost to the purchaser that it would cost the publisher to have the binding done; and, whereas, it has become a fad to place the number of the page at the bottom instead of the time-honored custom and efficient place at the upper left and right-hand corner of the page; therefore be it

RESOLVED, The members of the Indiana Academy of Science wish to go on record as favoring and recommending the following: That the author of all reviews and published articles append his full name, and it is preferred this to include his address; that book reviews conclude the review with the size of the book, the number of pages, illustrations, figures, maps, kind of binding and price. If price does not include delivery, to give weight of book; that all publications of a scientific nature, except those which are a part of a volume, be sent out bound either in substantial cloth or cloth back with stiff board sides; and that the paging should be at the upper right and left-hand corners of the pages. That this be published as a part of the next Proceedings and copy be furnished Science with request to publish.

Chairman Mahin of the Program Committee assumed charge of the meeting and introduced Father Walsh, President of the University of Notre Dame. Father Walsh gave an address of greeting and welcome to members of the Academy. In this address he eulogized the place of science in civilization and the idealism of the scientists. Response to the address of welcome was made by President Wade.

The reading of papers on the morning program then followed.

At a brief business session following the annual Academy dinner the following business was transacted:

The Nominating Committee made the following recommendations for officers for 1928:

President, E. G. Mahin, University of Notre Dame, Notre Dame.

Vice-President, W. N. Hess, DePauw University, Greencastle.

Secretary, R. C. Friesner, Butler College, Indianapolis.

Treasurer, M. W. Lyon, Jr., The Clinic, South Bend.

Editor, J. J. Davis, Purdue University, Lafayette.

Press Secretary, H. F. Dietz, State Entomologist's office, Indianapolis.

The Secretary and Editor were instructed to appoint their own assistants.

By action of the session these persons were declared elected to their respective offices.

Chairman Andrews of the Committee on Resolutions made the following report:

The members of the Forty-third Annual Meeting of the Indiana Academy of Science, assembled at the University of Notre Dame, hereby desire to express our thanks and appreciation for the generous and kind reception with which we have been received and entertained. We desire to thank especially the University of Notre Dame and its faculty, Reverend Matthew J. Walsh, President, for his words of welcome, also the Notre Dame Academy of Science. We thank also the following, all of whom have made willing contributions and rendered assistance in many ways: The South Bend Chamber of Commerce, The Studebaker Corporation, The South Bend News-Times, The South Bend Tribune, The Oliver Hotel, The La Salle Hotel, The Jefferson Hotel, Dr. Charles Stolz, Dr. A. S. Giordano, Mr. Fred Wiedman, Mr. W. A. Hare, and the South Bend University Club.

We appreciate and thank the University of Notre Dame for the use of its buildings, The Clinic for the use of its lantern, the St. Joseph Medical Society for mailing 325 programs. Finally, the appreciation of our reception at Notre Dame would not be complete without tendering our thanks to Dr. E. G. Mahin and Dr. M. W. Lyon, Jr., for their untiring and efficient work which has made our meeting so successful. To these and all others we repeat our thanks.

Chairman Enders of the Membership Committee made the following report of names of applicants for membership in the Academy:

Adams, C. F., Bacteriology, State House Annex, Indianapolis.

Andrews, Frances, Botany, 715 E. Tenth St., Bloomington.

Balas, George M., Physics and Mathematics, Mazon, Ill.

Bard, Frank B., Physics, Crothersville.

Beecher, Brazier K., Chemistry, 1125 N. Courtland, Kokomo.

Behrens, Otto, Jr., Biology, 804 W. Fifth St., Anderson.

Benton, Curtis, Entomology, Box 495, West Lafayette.

Bishop, George N., Physics, Mitchell.

Boatman, Luther, Chemistry, 128 S. Ohio St., Sheridan.

Bott, Herbert J., Geology, Geography, 1313 E. Campeau St., South Bend.

Brown, Jeanette, Biology, 518 W. North St., Muncie.

Bulfer, Rev. Gilbert, Chemistry, 511 W. Seventh St., Mishawaka.

Cho, Eung Tyun, Physics, Dept. Physics, Indiana University, Bloomington.

Copp, Paul Tillson, Mathematics, 300 Sylvania St., West Lafayette.

Crouch, Francis Eugene, Physics and Mathematics, Hanover.

Darnell, Warren Edwin, Biology, 102 S. Neal St., Indianapolis.

Doak, Kenneth D., Botany, Purdue Agric. Exp. Sta., West Lafayette.

Dunbar, Miriam, Botany, South Bend.

Edwards, P. D., Mathematics and Physics, 407 Riverside Ave., Muncie.

Gardner, Everett L., 425 W. Washington St., Monticello.

Geier, Esther Bernice, Botany, Star City.

Grainger, Gertrude, 110 Langhorn Lane, Lynchburg, Va.

Guthrie, Ned, Chemistry, Hanover.

Hale, Ruth Vivian, Botany, Oakford.

Hamlett, G. W. Deluz, Zoology, 701 Woodlawn Ave., Bloomington.

Harmon, Jesse, Chemistry, Lexington.

Harris, Ernest Harland, Physics and Chemistry, Hanover.

Jacobson, Walter Everett, Mathematics, 1016 Forty-first St., La-Grange, Ill.

Kaufmann, Fred H. O., Botany, 810 Lincoln Ave., Valparaiso.

Lambertson, Margot Garrard, Mathematics and Physics, Moores Hill.

Linville, Ralph B., Chemistry, Shelbyville.

Love, Louise M., Botany, 600 S. Nineteenth St., Terre Haute.

Malek, George, Physics, Gardner, Ill.

Navarre, Alfred Theodore, Geology, Chemistry, Hanover.

Price, J. Waide, Chemistry, 1219 N. Alabama St., Indianapolis.

Pritchard, Harmon, Botany, 357 Downey Ave., Indianapolis.

Peeves, June, Biology, Geography, Converse.

Reynolds, Hazel, Botany, 2128 Broadway, Indianapolis.

Robbins, Charles Kendall, Mathematics, 418 Vine St., West Lafayette.

Robertson, Geneva, Botany and Zoology, Route 1, Box 154, Kokomo.

Rose, James B., Physics, 495 Bosart Ave., Indianapolis.

Sheaffer, Frank E., Entomology, 4257 Winthrop Ave., Indianapolis.

Smelser, George, Biology, Box 159, Earlham.

Smith, Pressnall, Chemistry and Physics, 2007 Bulford Ave., Huntington.

Steiner, Loren Franklin, Entomology, Purdue Agric. Exp. Sta., West Lafayette.

Sturgeon, William E., Chemistry, 222 Tonti Ave., South Bend.

Swain, Louise S., Ornithology and Botany, 415 E. State St., Pendleton.

Swanson, Caroline H., Botany, 7816 Cregier Ave., Chicago, Ill.

Taggart, Matt F., 1528 Lincoln Way East, South Bend.

Test, Frederick H., Botany, 511 Russell St., West Lafayette.

Titus, Edna Virginia, Botany, Markleville.

Van Hoozer, Ethel Josephine, Geography, Geology, Route 6, Ft. Wayne.

Weir, Dewey C., Physics, Hanover.

White, Harold Everett, Pathology and Botany, 5452 Lowell Ave., Indianapolis.

Wills, Irvin A., Zoology and Physiology, 505 Calumet Ave., Valparaiso.

The following persons were proposed for membership, but have not met all of the requirements at the time of writing these minutes. They are all expected to fully qualify for membership and their names will be added to the regular roll as soon as they meet the requirements:

Emerson, Fred W., Biology, Earlham College, Earlham.

Hargitt, George T., Zoology, Syracuse University, Syracuse, N. Y.

Helman, Howard H., Ornithology, 15 N. Benton St., Peru.

Johnson, Willis H., Zoology, Crawfordsville.

Powers, Roscoe, Physics, Route 6, Box 384, Indianapolis.

Quick, Tunis J., Geology and Physiography, Columbus.

Ralston, George Wallace, Physics, Botany, Physiography, Milford.

Riley, Harlan K., Entomology, Purdue Univ., West Lafayette.

Smithberger, Andrew, University of Notre Dame, Notre Dame.

Teeters, Wilbur Oldroyd, Chemistry, 915 Campbell Ave., Indianapolis.

Trjitzinsky, Waldemar Joseph, Mathematics, 153 S. Garfield, Valparaiso.

Following the dinner, members enjoyed a most delightful concert given by the University of Notre Dame Glee Club, Mr. Joseph Casasanta, Director. At 8:15 Dr. Wilfred Osgood, Curator of Zoology, Field Museum of Natural History, Chicago, gave a public lecture on "Nature and Man in Abyssinia." This lecture was illustrated with slides and motion pictures and was greatly enjoyed by all.

RAY C. FRIESNER, Secretary.

THEODORE HENRY ALLEBACH.

EMLENTON, PENNSYLVANIA.

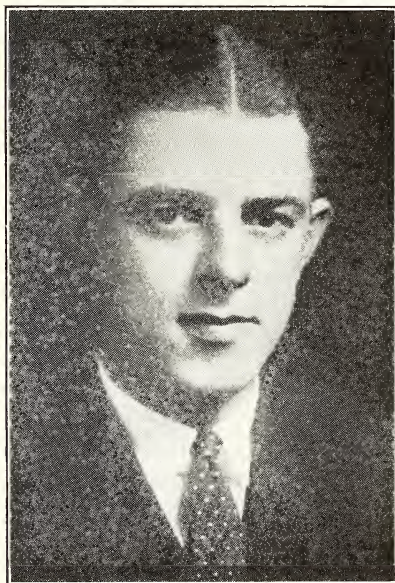
APRIL 9, 1903.

WEST LAFAYETTE, INDIANA.

JANUARY 11, 1927.

With the passing of Theodore Henry Allebach on January 11, 1927, the Indiana Academy of Science lost a member who had been elected to the organization scarcely a month before.

Mr. Allebach attended the grade and high schools in Emlenton, Pennsylvania, being graduated from the latter as an honor student in 1921. He entered Allegheny College the following September, having won by competitive examination the state scholarship for Venango, his



THEODORE HENRY ALLEBACH.

home county. Throughout his four years in college he had an excellent reputation as a student, particularly in mathematics and chemistry, and at the time of graduation had won *cum laude* honors and the Ballinger Prize for high-grade work in chemistry. He was interested in fraternity and college activities, and during the senior year was an assistant in the Department of Chemistry. St. John's Reformed Church, Sigma Alpha Epsilon, and Alpha Chi Sigma claimed him as a member.

Coming to Purdue University in the fall of 1925 as an assistant in the Department of Chemistry, Mr. Allebach soon established his reputation as an earnest and capable student in higher mathematics and graduate courses in chemistry. Although he did not have time to demonstrate his worth to the Indiana Academy of Science, the organization lost in Mr. Allebach one who had energy, interest and capacity and who had given promise of really productive work in his chosen field.

M. G. MELLON, Purdue University.

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WILLIAM FRANKLIN BAKER.

LAFAYETTE, INDIANA.
SEPTEMBER 10, 1883.

INDIANAPOLIS, INDIANA.
JUNE 30, 1927.

William Franklin Baker, son of Aaron F. and Sarah Baker, was born September 10, 1883, near Lafayette, Indiana, and died at St. Vincent's Hospital, Indianapolis, June 30, 1927.

His boyhood days were spent in Tippecanoe County, Indiana. On May 23, 1909, he was married to Letitia May Packer, of near Lafayette. To them were born two children, Lowell Franklin and May Louise, who with their mother live to mourn their loss.

Doctor Baker was graduated at Purdue University in 1909 with B. S. degree and from Indiana University School of Medicine in 1911 with degree of M. D.

Upon graduation he accepted a position in the Science Department of the Eli Lilly & Company laboratories at Indianapolis, serving also as industrial doctor there. From this position he was called to St. Vincent's Hospital to become the house doctor. He was also given charge of the X-ray and laboratory departments.

In the spring of 1920 he moved to Carmel, Indiana, where he had a large practice with people who have depended on him not only as a capable physician, but also as a true friend and brother.

When 14 years of age he united with the Christian Church of Pleasant Grove, Tippecanoe County. He was a member of the Marion Lodge of Masons of Indianapolis, of the Knight Templars, Shrine, Radiant Chapter of Eastern Star of Noblesville, of the Knights of Pythias and Pythian Sisters of Carmel. He was a member of the American Medical Association, of the Indiana Academy of Science and of the Hamilton County Medical Association.

Death was due to peritonitis. He was attended by the best of medical skill, but over-work had so reduced his vitality that surgery was impossible.

Dr. Baker was a student, not only of subjects directly related to his profession but of many others of general interest. He was gentle, thoughtful, cheerful, devoted to duty, retiring, but courageous. He shrank from everything in the manner of display or ostentation, and being a lover and student of nature, was impressed, as reflective minds ever are, with the essential truth, simplicity and rugged honesty of Nature and Nature's God, as opposed to the complexity, pretensions and inconsistencies of much of modern human life.

He had not been in vigorous health for a number of years, and had failed considerably in the last few months; yet against the advice of his fellow doctors, he had driven his body to the last full measure of devotion to his family and his practice.

He was modest and would answer these expressions of our love, as did the Great Physician, with "Why callest thou me good?" Nevertheless will we apply to our family doctor the words of the physician of our souls, "Greater love hath no man than this, that a man lay down his life for his friends."

REV. KARL R. THOMPSON, Lagro, Ind.

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ELIAS J. CHANSLER.

BICKNELL, INDIANA.

APRIL 8, 1855.

MITCHELL, INDIANA.

DECEMBER 31, 1926.

E. J. Chansler was born April 8, 1855. His education was such as could be had in the country schools of that day. His first schooling was acquired in a log building, the seats of which were made in a very rough manner. In reaching this school building he walked a distance of a mile and a half each way, taking a path through the woods, where wild turkeys and deer were often seen feeding. It was on these trips to and from school that his great love for birds and nature study was born. He was honest and industrious, and admired these attributes in others. He was greatly interested in the lives and the work of all men and women who are making a study of birds and nature. He had taken notes on the migration of birds for years, his dates and identification of species being seldom other than correct, as he prided himself in being accurate and exact in this work. His love was exceedingly strong for all scientific research work.

His death is regretted by all who knew him, for he leaves a vacancy which will not be easily filled.

WM. R. CHANSLER.

GLENN CULBERTSON.

SWITZERLAND COUNTY, INDIANA.
FEBRUARY 3, 1863.

HANOVER, INDIANA.
APRIL 23, 1927.

Nineteen years of close and understanding fellowship make it difficult to write with moderation of a friend's life. This is particularly so when the friend is a man like Glenn Culbertson, who achieved the rare distinction of being strong in many ways.

Born in Switzerland County, Indiana, in 1863, of Scotch parents, and reared in a consistently Scotch Presbyterian home and community, his life was the natural product of such heredity and nurture. He was



GLENN CULBERTSON.

educated in Hanover College, from which he received the A. B. degree in 1888 and the degree of Master of Arts in 1891. Subsequently he studied with Salisbury in the University of Chicago, by whom he was greatly influenced. In 1920 the University of Wooster conferred upon him the degree of Doctor of Science.

Professor Culbertson was principal of the Salida Academy in Colorado the years 1888 to 1890, and of the Presbyterian Academy in Bangkok, Siam, from 1890 to 1893. The latter year he returned to Hanover to become professor of physics and geology, which position he held to the time of his death in April of the present year. During recent years he was also vice-president of Hanover College and secretary to the Board of Trustees. He was elected to membership in the Indiana Academy of Science in 1895, and made a Fellow in 1899. He was presi-

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dent of the Academy during the year 1908, a regular attendant upon its stated meetings, and a frequent contributor to its Proceedings.

Professor Culbertson was an ardent churchman, for many years an elder in the Hanover church and clerk of its session. He was particularly active in the promotion of Sabbath school work locally and throughout the State. His service as a churchman was recognized by his election as moderator of the Presbytery of New Albany. Doctor Culbertson was equally active as a citizen. He was president of the Hanover Bank, a leader in public school affairs, the first man to be enlisted in the promotion of civic movements, and a fearless exponent of decency in local politics. He represented his district in the 1909 session of the state legislature.

As a teacher his classroom technique was always supplemented by infinite patience and thoroughness, and a gift for discovering and inspiring young men of special ability. He has thus produced a number of first-class scholars. His own scholarship was sound rather than extensive, but his viewpoint was thoroughly scientific. He found no conflict for himself between the hypotheses of modern science and his theology.

The primary characteristic in Professor Culbertson's personality was loyalty—loyalty to his family and his friends, to his home town, to his church, to his college, and to his convictions. To him duty was high privilege. Next to loyalty and his high sense of duty was his love of men, his love of little children, and of the "Great Outdoors." He was an outdoors man; he hunted, fished, explored and played. He was an expert gardener and orchardist. He was the outstanding athlete of his college generation; played center on the first championship football team in Indiana, and was a veteran of the diamond.

But it was in forest and field that Doctor Culbertson was most at home. He was a naturalist. No bird, bug, bee, plant nor fossil escaped him. He explored every cavern, cranny, fossil bed, and outcropping stone within tramping distance of Hanover. He knew the secrets of the streams of southern Indiana, and of hedge-row and hillside as well. He saw the first spring migrant, and heard the first warbler. The skies were filled with well-known friends. The problem on which he spent most time and labor was erosion in the hill country of southeastern Indiana and northern Kentucky. For 30 years he kept careful measurements of the cutting back of Clifty Falls in order to determine the rate of erosion and therefrom the age of Clifty Ravine. Possibly his best contribution to science is his archeological survey of Jefferson County and the adjoining counties of Indiana and Kentucky.

WM. A. MILLIS, Hanover.

CHARLES REDWAY DRYER.

ONTARIO COUNTY, NEW YORK.

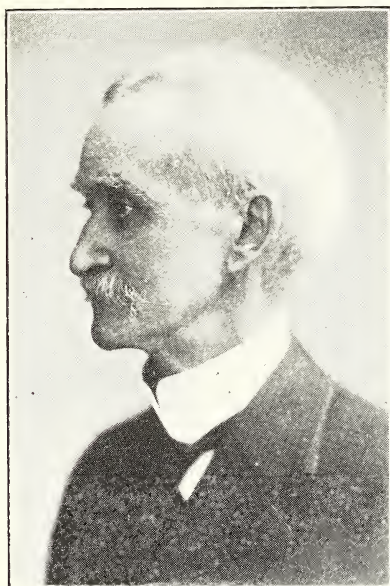
AUGUST 31, 1850.

FORT WAYNE, INDIANA.

MARCH 21, 1927.

Dr. Charles Redway Dryer, former Professor of Geology and Geography in the Indiana State Normal School at Terre Haute, died at his home at Fort Wayne, March 21, 1927.

He was born in Ontario County, New York, and received his early education in the academies of Macedon Center and Canandaigua. He graduated from Hamilton College, after which he studied medicine in the University of Michigan and University of Buffalo, from which latter



CHARLES REDWAY DRYER.

institution he received the degree of Doctor of Medicine. He practiced medicine for a short time but soon turned to teaching, which became his life work. In 1877 he became teacher of science in the Fort Wayne High School, in a day when the science teacher was expected to cover the entire field of physical and biological sciences. While an instructor in the high school he also taught toxicology and chemistry in the then existing Fort Wayne College of Medicine.

It is of interest to note that while his training in school had followed the lines of medicine and chemistry, his natural inclination drew him more and more into the field of geology and geography. Doctor Dryer was at heart a true naturalist and found some of his keenest intellectual delights in exploration and discovery. From 1886 to 1893 he

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served as an assistant on the Indiana State Geological Survey, surveying the six northeast counties, and working out in a very scholarly way the glacial geology of that region. When in 1893 the chair of geology and geography in the State Normal School became vacant and official inquiries were made about securing some person fitted to undertake this work, it was very natural that attention should be called to the work done by Doctor Dryer. He accepted the invitation to become the Professor of Geography and Geology, and held this position for 20 years.

He retired in 1913; spent a winter in study and lecturing at Oxford University, England, and his last years in Fort Wayne, doing considerable writing on geographical subjects and editing a series of new maps, since then very widely used in schools and colleges.

It is particularly appropriate that the Indiana Academy of Science should honor his memory. He was a charter member of the Academy, continuing his membership to his death. He was greatly interested in the work of the Academy, seldom failing to attend its sessions. He served as the President of the Academy in 1901, at which time he read as his presidential address a rather notable paper on the "Geography of North America."

He was a member of the American Association for the Advancement of Science, Association of American Geographers and the Royal Geographical Society of Great Britain.

His books include: "Studies in Indiana Geography," 1897; "Lessons in Physical Geography," 1910; "Geography Physical, Economic and Regional," 1911; and "Economic Geography," 1916.

He was also the author of numerous articles, a few of the important of which are represented in the accompanying bibliography.

As an inspiring teacher in his classroom, a productive scholar in his chosen field of study, and a man of wide reading and broad culture, he has permanently enriched the educational and scientific heritage of our State.

PAPERS BY DR. C. R. DRYER.

"The North America of Today and Tomorrow and Indiana's Place in It."—Proceedings of Indiana Academy of Science, 1911, pp. 37-54.

"Geographic Influences in the Development of Indiana."—Journal of Geography, September, 1910, pp. 17-23.

"The Maumee-Wabash Waterway."—Annals of Association of American Geographers, 1920, pp. 120-124.

"Morainic Lakes of Indiana; Wabash Erie Region."—Inland Educator, Vol. IV, pp. 63-69, pp. 120-124.

"A Century of Geographic Education in the United States."—Annals of Association of American Geographers, 1924, pp. 117-149.

"Natural Economic Regions."—Annals of Association of American Geographers, 1915, pp. 121-125.

"Genetic Geography."—Annals of Association of American Geographers, 1920, pp. 3-16.

"Studies in Economic Geography."—Geography Review, 1916, pp. 289-300.

L. J. RETTGER, Indiana State Normal School, Terre Haute.

CARL H. EIGENMANN.

FLEHINGEN, GERMANY.
MARCH 9, 1863.

SAN DIEGO, CALIFORNIA.
APRIL 24, 1927.

To Carl H. Eigenmann, teacher, colleague, friend, I address these brief remarks.

Sir: You came to America from Germany while still a boy. You entered Indiana University, where you obtained the degrees of A. B., A. M., and Ph. D. It was while here that you met, among others, David Starr Jordan, who revealed to you the possibilities in the field of Zoology. It was Jordan's enthusiasm and love for the subject which gave you the



CARL H. EIGENMANN.

inspiration. This contact was the spark which kindled the blaze. The materials were already present. The initial stimulus was all that was needed. This fire within you continued to burn brighter and brighter until disease entered, wedge-like, to force you toward the grave. During your active career you accomplished many great things and were the recipient of many honors. You were Professor of Zoology at Indiana University from 1891 to the time of your death. You were Dean of the Graduate School at Indiana University from the time of its organization in 1908, and you were the founder and director of the Biological Station from its beginnings in 1895. During your productive years, you did three things which stand out pre-eminently. The first is your work on the segregation of the sex cells of *Cymatogaster*; the second is your work on the blind vertebrates of North America; and the third your

studies on the fishes of South America. In the two latter fields, you became the leading authority. In recognition of this work you were elected to membership in many scientific societies, including the National Academy. These accomplishments are truly great, but perhaps even greater was your inspiration to students and faculty of Indiana University, to members of this Academy, and to biologists of the State and Nation.

Sir, we regret that you are gone. We miss the friendly smile, the cordial handshake, the witty remark, and the inspiration which your presence always aroused. On the other hand, we rejoice in your many accomplishments and in the fact that your influence will continue.

PAPERS BY CARL H. EIGENMANN.

1. A review of the American Elotridinae. (With Morton W. Fordice.)
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2. Notes on skeletons of Etheostomatinae. (With David Starr Jordan.)
Proc. U. S. Nat. Mus., VIII, pp. 68-72. 1886.
3. A catalogue of the fishes of Bean Blossom creek, Monroe county,
Indiana. (With M. W. Fordice.) Proc. Acad. Nat. Sci. Phila.
for 1885, pp. 233-252. 1886.
4. A review of the genera and species of Diodontidae found in Ameri-
can waters. Ann. N. Y. Acad. Sci., III, pp. 297-311. 1885.
5. A review of the American Gasterosteidae. Proc. Acad. Nat. Sci.
Phila. for 1886, pp. 233-252. 1887.
6. A review of the Gobiidae of North America. (With D. S. Jordan.)
Proc. U. S. Nat. Mus., IX, pp. 477-518. Nov., 1886.
7. Folk-lore of a German village. Current, V, No. 124. 1886.
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17. *Cyprinodon californiensis*, Girard. (With R. S. Eigenmann.) W. Am. Sci., V, pp. 3-4. Sept., 1888.
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19. On the development of California food fishes. Am. Nat. XXIII, pp. 107-110. March, 1889.
20. Preliminary descriptions of new species and genera of Characinidae. (With R. S. Eigenmann.) W. Am. Sci., VI, pp. 7-8. April, 1889.
21. Description of new Nematognathoid fishes from Brazil. (With R. S. Eigenmann.) W. Am. Sci., VI, pp. 8-10. April, 1889.
22. Preliminary notes on South American Nematognathi, II. (With R. S. Eigenmann.) Proc. Calif. Acad. Sci., 2d ser., II, pp. 28-56. Aug., 1889.
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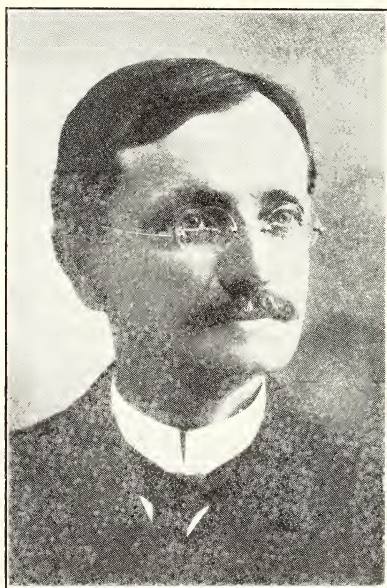
FERNANDUS PAYNE,
Indiana University.

CHARLES WESLEY HARGITT

DEARBORN COUNTY, INDIANA.
MARCH 28, 1852.

SYRACUSE, NEW YORK.
JUNE 11, 1927.

Among the scientific men whom Indiana delights to honor none ranks higher than Charles Wesley Hargitt who died June 11, 1927, at his home in Syracuse, New York, after a brief illness. The formative period of his life was spent in Indiana. Among the rugged hills of Dearborn County near the village of Bright, on a farm, he first saw the light March 28, 1852. His parents, Thomas and Mary Hargitt, were an unusually strong type of religious people of the pioneer day. While on the



CHARLES WESLEY HARGITT.

farm he became a lover of nature. The flowers and trees and rocks he early learned to observe and think about and ever after it was his delight to roam over these hills of Dearborn County in search of the secrets of nature.

His early education was secured in the rural schools of his community. He became a leader and took part in the life of his neighborhood. He then went to Indianapolis where he completed the grammar and high school work. He then began teaching in the rural schools of his native county. After teaching several years, he entered Moores Hill College in 1873 under the presidency of Dr. F. A. Hester and graduated under that of Dr. J. P. D. John, receiving the degree of B. S. After graduation he entered the ministry of the Methodist Episcopal Church, serving effectively for seven years in Indiana and Texas. Cer-

tain throat trouble developed which made him decide to enter the ranks of the college professor.

To prepare for his new work he entered the Massachusetts Institute of Technology in Boston, in 1884, where he remained until the summer of 1885. He was then offered the chair of Natural Science in his Alma Mater, which he accepted and filled with distinction until 1888 when he resigned to accept the chair of Biology and Geology in Miami University at Oxford, Ohio. While here he pursued graduate work in Ohio University, from which he received the degree of Doctor of Philosophy in 1890. In 1891 he resigned to accept the chair of Biology and Geology in Syracuse University, succeeding Dr. L. M. Underwood. Later Botany and Geology were organized into separate departments so that he became professor of Zoology and Director of the Museum of Natural History. He remained at the head of this department until 1921, when he withdrew from the headship of the department and was made Research Professor in Zoology, devoting his entire time to study and writing until his death.

"He was active in many other phases of professional, scientific and educational work, serving as Assistant Director of the Cold Spring Biological Laboratory, N. Y., 1891-93, and trustee of the Marine Biological Laboratory at Woods Hole, Mass., 1900-21. He studied in Europe at the Zoological Station at Naples in 1894, 1903, 1910. He was instrumental in organizing the Onandaga Academy of Science of the New York State Teachers Association and its president in 1899; vice-president of the American Association for the Advancement of Sciences, and chairman of the Zoological Sciences in 1902. Membership in scientific organizations included the American Association for the Advancement of Science, American Association of Zoologists, American Society of Naturalists, American Genetic Association, Washington Academy of Sciences, Indiana Academy of Science, and others. His membership in the Indiana Academy of Science was retained for many years after leaving the state and interest in its work and membership was maintained to the end of his life. It was with deep regret that he could not attend the spring meeting of the Academy at New Harmony, May 13-14, 1927. He deeply appreciated a telegram of cheer and greeting sent to him by the Academy at this session."

Dr. Hargitt was original in his thinking. From boyhood he exhibited the inquisitive turn of mind. This led him to observe nature closely. It was perfectly natural for him to delight in research work. The laboratory became his workshop, and some of the secrets of nature were discovered by his keen eyes and mind. To carry out this desire, he spent much time in the marine laboratories as well as in his own.

As a teacher he exerted his greatest influence. Not only did he understand his subjects thoroughly but he had an enthusiastic scientific spirit which was imparted to his students. They could not resist this impelling enthusiasm. Furthermore, he worked in such close touch with his students in the lecture room, in the laboratory and in the field that they were delighted to study the deeper truths of nature. Moreover he was a lover of his fellow men as well as a devoted follower of the Great Teacher and warmth of personality exerted a strong influence

upon all who came under his instruction. On account of this religious attitude, a splendid and sane influence on spiritual and scientific questions was developed in the biological department. The spirit of discord between science and religion did not exist. He wrote many articles for the publication in national papers to stimulate and instruct the people in right thinking on these controversial questions.

As he was a strong teacher, so was he a true educator. He as a member of the faculty was one of the leaders who helped to mold the policies of that university. The courses of study came up for revision during his early days in Syracuse University. He was a strong advocate of modernizing these courses so as to be in harmony with the leading universities of the country.

He was the author of *Outlines of General Biology* as a guide to laboratory study. It has gone through several editions and is considered one of the best published. His first scientific paper read before the Indiana Academy was on "Recent Notes on *Scaphiopus holbrookii* in 1888". From that day to the day of his death his pen had been busy writing for the scientific papers and governmental publications. About 100 such articles have been published.

He was frequently called upon to give lectures before scientific bodies as well as before popular audiences. All his life he found occasions to fill the pulpits of various churches. Many of these sermons and lectures were published. One of the finest articles of appreciation of Doctor Hargitt was recently published in *The Post Standard* of Syracuse by Prof. W. H. Mace, the historian who went to Syracuse the same year as did Dr. Hargitt. They were close friends during all those years.

The author of this sketch is in a position to judge of the life and work of this good man. He delights to call him his scientific father for he was a student under him while he taught in Moores Hill College. His impress was made in the laboratory and it continued throughout life. A correspondence was kept up all through the years and was rich in friendship and scientific lore.

As a man in society he was always interested in the highest culture of the people in home, in school, in church, and in state. Character building meant more to him than anything else. All his writings reflected the scientific mind and the cultured gentleman.

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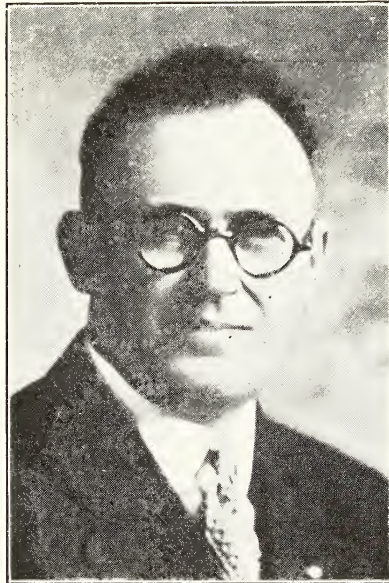
ANDREW J. BIGNEY,
Evansville College.

CLAUDE H. HARSHBARGER

ROACHDALE, INDIANA.
DECEMBER 29, 1889.

DANIA, FLORIDA.
APRIL 3, 1927.

Claude H. Harshbarger was born near Roachdale, Indiana, December 29, 1889. He received his early education in the schools of Putnam County, and graduated from the Roachdale High School in 1908. During the following years he taught in various schools, was cashier in a bank, and was for a time City Clerk of Roachdale. In the meantime, as circumstances permitted, he was slowly making his way through Indiana University, from which he received the A. B. degree in 1924.



CLAUDE H. HARSHBARGER.

August 7, 1913, he was married to Alma Barnard, who, with two children, Lena Faye, aged 10, and Richard Barnard, aged 6, survives him. In the summer of 1925, after a serious illness, he went to Florida in search of a more favorable climate, and made such improvement that he was able to assume full duties as principal of the schools of Dania in September. After a successful year he felt much encouraged and was just beginning a second year's work when the hurricane of September, 1926, reduced his school plant to a wreck and almost entirely destroyed the town. His final illness is attributed by his physicians to the overwork and exposure incident to the storm and the rehabilitation of the town and the rebuilding of the school.

Mr. Harshbarger was just approaching the best years of his life and his loss is felt most keenly by this Academy and by the community in

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

which he lived. His qualities of citizenship and his popularity among those who knew him are attested by the fact that he was a member of the Christian Church of Hollywood, Florida, the Roachdale Lodge, No. 602 F. & A. M., the Scottish Rite and Shrine of Indianapolis, and the Rotary Club of Hollywood.

I visited him in the fall of 1925, only a few weeks after he began his duties as principal of the Dania schools. Florida was at the height of its period of prosperity; the enrollment in the Dania schools had doubled since the beginning of the term; temporary buildings were scattered over an acre of ground, and more were being built. It is seldom that a teacher going into a new community meets with such difficulties of organization and administration; but the system was moving smoothly, and plans were being made for permanent facilities to take care of the children of the large winter population that was reasonably expected in the years to come.

I visited Dania again in April, 1927, only a week after his death. The hurricane had done its work with a thoroughness that can be realized only by those who knew the lower east coast both before and after September, 1926. On the site of the old school building of Dania a new one was nearing completion, and in it were embodied the ideas that Mr. Harshbarger had worked out. People with whom I talked told of the fight he had made, in the face of discouragement, wreck, and financial disaster, for the kind of school that the town should have, and no one seemed to be sorry that he had won.

Mr. Harshbarger's major work in his undergraduate days was in botany. He did no graduate work, and had published no papers. His later interest and efforts were chiefly in another field, and, both in his home community and in Broward County, Florida, he will long be remembered for his constructive citizenship and his professional ability as an educator.

PAUL WEATHERWAX, Indiana University.

PRESIDENT'S ADDRESS.

MORE SCIENTIFIC EDUCATION; LESS EDUCATIONAL MEASUREMENT.

FRANK B. WADE, Shortridge High School, Indianapolis.

Mr. Chairman, and members and guests of the Indiana Academy of Science: My title seems to imply that there is coming to be some sort of conflict between the ever-increasing wave of educational measurements and the teaching of science. It is because I suspect that to be the case that I have chosen the kind of title that I did. It seems to me that this fever for testing is but a symptom of a deep-seated disease in American educational method. In the recent report of the Carnegie Foundation for the advancement of teaching, on "The Quality of the Educational Process in the United States and in Europe," I find what I think is an account of the disease itself. In discussing the faults of our secondary schools the report cites as the third of four defects the following: "The curriculum is a rope of sand, without texture or organization. Effective organization through related ideas is thereby sacrificed *to the mere registering of information.*" The italics are mine. Again we find, "For fear of evaporation the process is checked up at once—daily recitation, written review, monthly test, and term examination. These concluded, responsibility ceases, and 'credit' is recorded, of which no future misstep, even though it discloses total ignorance, can ever deprive the pupil." In contrast with this state of things, the Carnegie report tells us that in Europe "The pupil who knows from experience that a new fact or a principle will reappear year after year in modified forms or with enlarged applications confronts it in an attitude unlike his who believes it will be shelved forever after the next term examinations. It is to his obvious interest to understand it. *There are no tests or examinations in the American sense from one end of the curriculum to the other.*" Again the italics are mine.

I should say at once that I hope and expect to find in you a sympathetic audience and one that has little need of what may seem like a warning message. It is because it seems to me that there is need in various quarters for consideration of this topic that I wish to have it go on record in the Proceedings of the Academy at this time. Surely we members of this State Academy of Science should be concerned about the best methods of inculcating the scientific spirit in the students who are one day to take our places, whether in scientific education, research or applied science.

May I make it clear at this point that my remarks are intended to apply solely to conditions in secondary education. Every teacher should stay within the field with which he is familiar.

Like a preacher, I have taken a text for my discourse. Unlike the preacher, however, I did not find my text in the Holy Scriptures. It came rather from an Omega Oil advertisement of some 25 years ago. Some of you will recall the Omega Oil Philosophy posters, each with its long line of geese winding down the way toward the reader and each poster carrying a pithy saying. The one I quote read: "Don't inquire into a hungry man's history! Give him something to eat!" You all see the point. I submit the question, "Have we educators not been a bit too inquisitive recently as to the measure of the progress of our pupils and perhaps somewhat negligent of our duty in connection with inspiring them to dig in and thus make real progress?"

I would not like to be regarded as unprogressive in these matters, but I have no objection to being considered as conservative. My thought is this: Is it not time we were putting the new so-called "science" of educational measurements in its proper place? Should we not attempt to view it in its proper perspective? We should give it due credit for the real progress that it has made. A number of most ingenious psychological tests of intelligence have resulted from the labors of workers in that field. May I suggest, however, that experienced teachers can usually estimate rather closely the "I. Q.'s" of pupils with whom they have been working for a time. It is with the newcomer that the intelligence test is most useful. Even here the results must be "taken with a grain of salt." I recall a case in point. A certain pupil was graded very low after one of the conventional intelligence tests. Later, on being tested in another and very much larger school, the pupil ranked first among several thousand pupils. Investigation showed that on the occasion of the previous test the pupil had needed to go to the toilet, but, on raising the hand, had been told by the teacher that no questions could be answered until the test was over. The "I. Q." number that resulted can be imagined. On that occasion it was the teacher's "I. Q." that needed investigation.

We must consider too that the character factor counts in educational results as well as the intelligence quotient. Often our "failures" are of high intelligence but of low moral purpose. Weak wills may be yoked to high intelligence. Is it not true that much of our energy as teachers should be expended in trying to stimulate our pupils to greater effort? Does not *inspiration* often go farther than *examination*? Our friends of the educational yardsticks have avoided these intangibles. They have stuck very largely to the *informational* side of *knowing*. For *feeling* and *willing* they have no gauges. Yet most of the influences of the great teacher are probably exerted through his pupils' feelings stirring their wills to action.

Shall we not then recognize the relatively secondary character of the subject-matter which we teach; and apply ourselves to *educating* boys and girls, young men and young women? And if we are to do well at this we cannot afford to spend too much time using artificial and admittedly not altogether dependable methods of measuring achievement in the memorizing of facts. In the light of the foregoing premises how unwise it is to conclude, as did one enthusiast in educational measure-

ments, that since certain pupils who had had no chemistry did better on a test than certain others who had taken one semester of chemistry, therefore those pupils who had had no formal instruction should be put at once into the second semester's work. Shades of all educators of all past ages! Did not the most valuable part of the semester's work lie in the experiences of laboratory and of classroom and in the intercourse between pupil and pupil and between pupil and teacher? Were not all of those pupils going on into life and fewer than five per cent into chemistry?

You who know me so well will not be misled into thinking that I am not an admirer of scholarship. Fine scholarship is an admirable, an excellent thing. It may be had, however, only by those who, having high native intelligence, are taught to make good and efficient use of it in acquiring, classifying, storing and learning how to apply knowledge. The teacher who can stimulate and guide the learner to do these things—especially the latter—has his hands full without making very large use of objective tests. His examinations will have to be largely in the nature of teaching-exercises calculated to lead his pupils to attempt to apply in new situations the essential facts that they should have previously learned. It is only by repeatedly encouraging her fledglings to try their wings that the mother bird teaches her young to fly.

In fairness to some of the more recent tests, some success has been had in bringing in questions that give the pupil a chance to use his ability to apply his knowledge. It is, however, admittedly a more difficult type of question to prepare than the questions that deal with mere information, and few "thought questions" appear in most tests.

By way of constructive criticism may I suggest that instead of spending an undue amount of time, as I expect some teachers are doing, upon what is considered by its devotees scientific testing, we should devote much time and energy to an attempt to discover how we may more effectively arouse the interest of our students in the subjects we are teaching. To do this we must study the present interests of our boys and girls and make contacts with them. We should also study the tactics of all great teachers in all times and in other countries and learn of them. The well-considered opinions of present-day educators should be respected, studied, weighed, and suitable use should be made of them. Although our modern school of scientific testers scoffs at "mere opinion," let us remember that great businesses are successfully run by boards of directors—men of experience, who may make due use of statistical evidence in arriving at their conclusions, but who rely finally on their own judgment in making their decisions. So too should we teachers make due use of the various methods of testing results now available to us, but let us not fail to be governed by our common sense.

As the irate mother, whose boy had been beaten by the teacher, wrote, "Don't lick him! Larn him!" So I say, "Don't test him! Teach him!"

NEW HARMONY.¹

DAVID STARR JORDAN, Stanford University, and AMOS W. BUTLER,
Indianapolis.

The Indiana Academy of Science celebrated from May 12 to 14 the Centennial Anniversary of Western Science in the town where scientific investigation in that region practically began. New Harmony lies in Posey County, the most southern of the 92 counties of Indiana. Posey County occupies the rich and level farming land of the southwest corner of the State, bounded on one side by the Ohio River, on another by the Wabash, the Ohio separating it from Kentucky, the Wabash from Illinois. On the east side, on the Wabash, is the village of New Harmony, with about 1,200 inhabitants, the scene of the great communistic experiment of Robert Owen, who was a prosperous mill owner, well known for his co-operative industrial effort at New Lanark, Scotland. Fertile soil, abundant water, salubrious climate, furnished a favorable setting.

A century and more ago the civilized world began to feel that the age of business competition was passing, and that a new social and industrial era was at hand. This was not the first time nor yet the last when ideal conditions seemed imminent in human relations. Franklin once indicated that if every one would work three hours a day at something useful, poverty would be banished and all men might spend the afternoon of each day and the whole afternoon of life amid the consolations of philosophy, the charms of literature or the delights of social intercourse. In the words of Robert Dale Owen, men "looked forward to the time when riches, because of their superfluity, would cease to be the end and aim of men's thoughts, plotting and lifelong stirring; when the mere possession of wealth would no longer confer distinction any more than does the possession of water, than which there is no property of greater worth."

With the same thought, the geologist, William Maclure, prominent in the Philadelphia Academy of Natural Science, refusing to invest money in Philadelphia, asserted that "land in cities could no longer rise in value. The community system must prevail and in the course of a few years Philadelphia must be deserted and those who live long enough may come back here and see foxes looking out of the windows."

Entranced by these ideas, Robert Owen, of New Lanark in Scotland, successful author of various reforms, came to America to put his conceptions and experiences into practice. With Owen was associated William Maclure, one of the eminent geologists of the day and a friend of scientific men, many of whom he induced to join in a great humanitarian enterprise.

¹ Reprinted from *Scientific Monthly*, Nov., 1927, pp. 468-470, by order of the Executive Committee.

The property at New Harmony was bought by Owen from George Rapp, the head of a celibate German communistic cult known as the "Economists." These then left Indiana to form a settlement in central Pennsylvania which they named Economy. Under Rapp's rule this experiment was financially successful because it was dominated by a single will. Both his ventures, in Indiana and in Pennsylvania, were ideal Theocracies, ruled autocratically under divine right. According to Rapp an angel appeared at his bedside every morning to direct what each member of the community should do each day.

At the foundation of New Harmony, Maclure and others came down the Ohio River on a boat named "The Philanthropist." This became locally famous as "The Boatload of Knowledge." It contained all the men of science whom the geologist was able to reach and influence. His plan was to build up in this community a School of Industry which should teach the "Conquest of Nature." Farmers should rise above the status of "tillers of the soil" to leading the land to do its best. A magazine was founded, called "The Disseminator of Useful Knowledge, Containing Hints to the Youth of the United States from the School of Industry." In "The Disseminator" appeared from time to time valuable articles from naturalist members of the community.

Thomas Say, one of the founders of the Philadelphia Academy of Natural Science, formerly a member of Long's Expedition to the Rocky Mountains, wrote learnedly on insects, birds and shells. Another pioneer naturalist, the French artist, Charles A. LeSueur, also came to New Harmony with the "Boatload of Knowledge." A friend of Cuvier, with an established reputation as naturalist and artist, he had been around the world on La Perouse's celebrated voyage. In the drawing and painting of animals he showed rare skill, and his woodcuts of the fishes of the Great Lakes are among the most lifelike ever published. It was he who painted the drop-curtain of the Community Hall. This represented Niagara Falls with "the other marvel of the New World," the rattlesnake, coiled beside it. Richard Owen was a favorite with LeSueur and once told Dr. Jordan how he used to wade barefoot in the bayous of the Wabash to gather mussel shells for the gifted naturalist. Three of the sons of Robert Owen—David Dale Owen, Robert Dale Owen and Richard Owen—were each highly gifted, David and Richard as geologists, Robert in literature and the humanities. Robert Dale Owen was long and favorably known as a charming writer, one of the group of essayists who early gave to the *Atlantic Monthly* its high literary character. As a member of the Indiana Legislature he had a large part in shaping the public school system of the State. David Dale, the second son, and Richard, the youngest of this remarkable family, were intimately associated throughout their lives. David, afterward the first United States geologist, was especially interested in fossils and minerals. He classified the great collection left by Maclure, which, with his own extensive accumulations, afterward formed the Owen Museum (of 85,000 specimens) of Indiana University, one of the largest displays of Paleozoic fossils in America until its partial destruction by fire in 1883. In 1886 a large part of this collection was sent to the United States National Museum,

in return for the re-identification and restoration of labels lost or destroyed by the fire. The only daughter of Robert Owen who came to America, Jane Dale Owen, a woman of much ability and of considerable scientific knowledge, married Robert H. Fauntleroy, astronomer and meteorologist in the service of the United States government. Upon his death he was succeeded by his son-in-law, Professor George Davidson, the well-known astronomer of the United States Coast Survey, who took up his abode for a time in New Harmony.

The New Harmony schoolmaster, Dr. Joseph Neef, was a blunt, plain spoken, honest man, a great favorite with his pupils. An Alsatian by birth, he had been priest, soldier and at the same time a mathematician of high ability—for a while, also, associate of Pestalozzi in his famous school at Yverdon, Switzerland. Pestalozzi once commended him as "an earnest, manly worker, who did not disdain to occupy himself with the elements of science." Maclure met Neef in Paris, and brought him over to America. "It is my highest ambition," said Neef, "to be a country school teacher amidst a hardy, vigorous community." His two daughters both married Owens, the one David Dale, the other, Richard. Another who came on "The Philanthropist" was the Dutch scientist, Dr. Gerard Troost, who remained for some time, becoming state geologist of Tennessee.

Richard Owen was professor of natural science in Indiana University from 1863 to 1879, where Mr. Butler was one of his pupils. Dr. Jordan was chosen as Richard Owen's successor. Owen was a man of broad scholarship and large sympathies as well as of courtly manners. Dr. Jordan gave a lecture in New Harmony with Dr. Owen in the chair. He was then very old and heard not a word which was said, but by watching the faces of the audience he was able to exhibit every appropriate shade of feeling for which the address seemed to call.

Many distinguished visitors came to New Harmony, among them Sir Charles Lyell, greatest of all geologists, who was once a guest of the Owens. Constantine Rafinesque, eccentric and ultra individualist, also passed that way "on foot, with a bundle of plants under which a peddler might groan."

The New Harmony experiment, based on Communism, lasted but a short time. Its failure was in its economics; its successes in the study of nature. Some blamed Owen himself for his refusal to deed to the Community all its property. He chose to wait to see how it turned out. Common opinion asserts that it had "too many managers and too few workers." Common ownership requires community of spirit. Drones and workers can not have equal access to honey cells, a fact that has many times been demonstrated. But from another point of view—that of common life among free spirits—"Gemeingeist unter freien Geistern"—the episode must be reckoned a great success. It marked the advent in the Middle West of serious work in science. More than any others, Owen and his sons were advance leaders in the progress. The beginning of the United States Geological Survey was the work of David Dale Owen, and till near the time of the Civil War, its actual headquarters were at New Harmony. The Brookville Natural History Society,

founded by Amos W. Butler in 1881, caught its first inspiration from Owen and Say and it was the chief influence in the founding of the Indiana Academy of Science in 1885.

After the failure of the Owen venture New Harmony continued as a center of scientific activity. The United States Geological Survey, the work of the United States Coast and Geodetic Survey Meteorological Records and the libraries begun by William Maclure in New Harmony extended throughout the State. It was a training school for young geologists. Among those who worked there were Edward T. Cox, state geologist of Indiana; J. G. Norwood and A. H. Worthen, state geologists of Illinois; B. F. Shumard, state geologist of Texas; Dr. Robert Peters, Dr. Joseph Leidy, F. B. Meek and Leo Lesquereux.

It is fortunate that so much has been preserved for a century, that the Indiana Academy of Science has felt the urge to pay honor to the memory of these pioneers. For more and more, New Harmony is becoming a place of pilgrimage for the social scientist, the educator, the historian, the student of the natural and of the physical sciences and the tourist. A beaten pathway has been made to the door of New Harmony.

AERIAL PHOTOGRAPHY FOR INDIANA.

T. M. BUSHNELL, Purdue University.

Aviation in general is making marvelous progress marked by a series of spectacular achievements attended by wide publicity. The public is becoming "air-minded" and the present generation is "born to the air" and takes flying for granted. However, most of us can remember the days when "Darius Green and his flying machine" was one of the popular recitations at the Friday afternoon exercises at the little old school and we naturally hesitate at each new scheme of enthusiasts.

It is the purpose of this paper to discuss one of the least advertised phases of aviation; namely, aerial photography—with special emphasis on the status of this work in Indiana and to suggest possibilities of this development in the future.

Aerial photographs are in every periodical these days, illustrating articles and advertising different things. Most of these pictures are obliques because they appeal to the eye of earth dwellers more than do vertical pictures which really constitute the most extensive and valuable product of aerial photography. Vertical pictures are used chiefly in various kinds of mapping, as in connection with standard topographic surveys, location of power lines, roads, railroads, rights-of-way of all kinds, reservoir surveys, flood control, drainage, city planning and zoning, traffic studies, timber cruising, tax appraisal, oil exploration, home sites, geological and ecological studies. You need look no farther than the 1926 issue of *Proceedings of the Indiana Academy of Science* for a good reference on a use of aerial photography.¹ Several extensive bibliographies on aerial photography have been compiled.²

Over 50,000 square miles of standard topographic surveys have been made by the U. S. Geological Survey with the aid of aerial photos. New York City and Los Angeles have been covered by pictures. One process has been perfected by which topographic maps can be made direct from aerial photos.³ After comparing two maps of the same territory, one made by this photo process and the other by standard methods, the chief topographic engineer of the U. S. Geological Survey wrote that they agreed fairly well but the "most marked difference is due to the marked superiority of the photographic method in refinement of

¹ *Aeroplane Photography and Ecological Mapping* by Stanley A. Cain, *Proc. Ind. Acad. Sci.* Vol. 36, 1926, pp. 269-272.

² *Bulletins of the Fairchild Aerial Surveys, Incorporated*, 270 West 38th Street, New York City: A list of references on aerial surveying by the library of the Bureau of Railway Economics: U. S. Department of Commerce: A bibliography prepared by the Engineers Corps library and published in *Professional Memoirs*, Vol. 10, 421-436 and 560-590 and 855-884.; *Aircraft Year Book*.

³ Paper 1606, *Aeroplane Topographic Surveys* by George T. Bergen, p. 627, Vol. 90. *Trans. Amer. Soc. Civ. Eng.* (June, 1927).

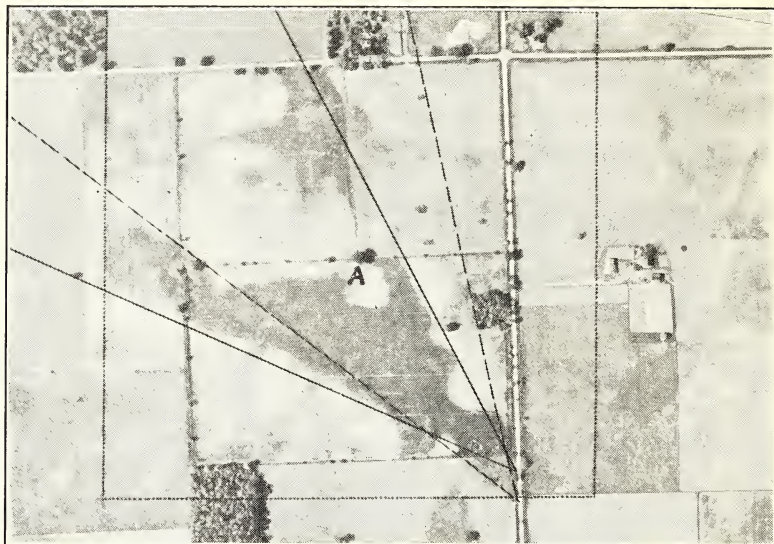


Fig. 1.—Aerial photograph of land located about two miles north of Purdue University. The dotted square shows area covered by figure 2. The angle between solid lines shows area in figure 3. The angle between dashed lines shows area in figure 4. The letter A locates the same large tree in figures 1, 2, 3 and 4. Photograph by U. S. Army Air Service, May 20, 1926.

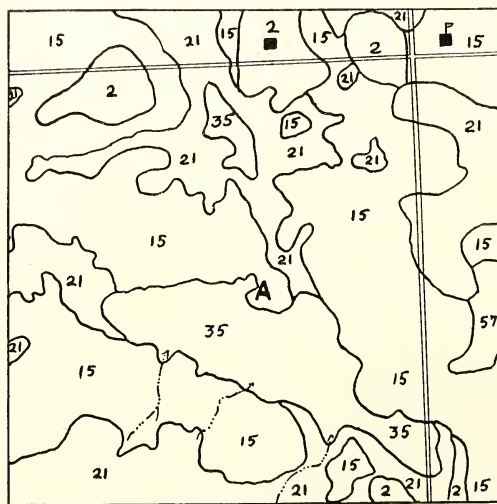


Fig. 2.—Soil map based on aerial photo (figure 1) and field studies.



Fig. 3—Photograph, June 20, 1926, of land located within solid line angle on figure 1. Note how the growth of wheat has concealed the light and dark soil areas which are so visible in figure 1.

detail. This is particularly obvious in such features as drainage lines and also applies to contours."

The title of one article is, "Air Surveying 15,000 Square Miles of Forest in Burma,"⁴ It seems that this country to which we send missionaries has photographed an area nearly half as large as our State while we apparently have aerial pictures of only a few hundred square miles.

As far as I can learn, our largest aerial survey is about 100 square miles which were photographed in Martin and Lawrence counties for the State Highway Commission to aid in the location of a state road.



Fig. 4—Photograph taken in November, 1927, showing land located within dashed line angle on figure 1. The plowed field shows the land in best possible condition for terrestrial mapping of the soils. Note how quickly the visibility of soil conditions fades out in the distance; also how little can be seen in corn fields even at short range.

⁴ Flight, Vol. 17, pp. 826-827, Dec. 17, 1925.

Some 30 square miles in Harrison County have been mapped for commercial purposes. About 30 square miles were photographed by the Army Air Service near Lafayette to help the U. S. Geological Survey make a special topographic map for the Purdue Military Department. A similar area was mapped at Culver. Transmission line strips were photographed near Fort Wayne, Marion, South Bend and Muncie. The Bacon's Swamp area of less than one square mile was photographed for ecological studies. As there are four firms in Indiana and many more in adjoining states which report aerial photography as one of their activities, there must be a number of other areas mapped in Indiana and I would like to request at this time detailed information from anyone who knows about any aerial work that has been done or is being considered.

The interest of my department in aerial photography arose out of the needs of soil survey. Dirt is too common to be an object of interest to most folks, but soil surveyors are devoted to the interests of "Pedologie" or soil science, which is as distinct from agronomy as botany is, although, like botany, it makes contacts with agronomy and practical agriculture in many ways. The soil map, which many might consider the most conspicuous product of soil survey, is simply a graphic record of where different soils occur and is usually made by rapid and simple methods. However, when we once enter the map making game, we assume a heavy responsibility for accuracy and reliability. On one hand, we have high standards set by the board controlling all government maps; on the other hand, we find a map which "might be" 99 per cent perfect is likely to be condemned by some citizen if a mistake is made on his property. The only standard permissible in mapping is perfection comparable to that found in dictionaries. Thus, our soil students in soil survey ought to be expert cartographers. Soil surveyors often find map making taking most of their time and energy to the detriment of soil studies. Gathering soil data in the field is a form of research work in which no one supervising the work has a chance to review original data without considerable labor in reaching the exact spot on the earth's surface where some problem may occur. For our work, we regard aerial photos as a means by which an inspector or any person can actually see the surface indications in any locality and check the work of field men. Pictures give us accuracy of detail and reliability not possible in any other way and at the same time allow us to cover the ground more rapidly. Pictures would avoid such errors as those due to local magnetic attraction, mistakes in measurements and especially in location of features which ordinarily are sketched by eye between points actually located by instruments. In many states, soil survey maps are supplemented by elaborate systems of notes relative to farm conditions. These could be largely replaced by photos on file at experiment stations which would show a wealth of detail about layout of farms, buildings, fences, crops, woodlands, erosion and streams, which can not be shown on published maps.

Figure 1 is a good example of conditions prevailing in the "black and white" soil region of central Indiana. This aerial picture shows the roads, fence lines, land lines, etc., which are used in constructing

a base map. It shows trees, houses and many other landmarks extremely useful in locating any feature which should be mapped. It even outlines perfectly many soil boundaries even under cover of crops, although there are other soil boundaries shown on the soil map in figure 2 which are not shown by the aerial photo, but must be determined by field studies as to character of subsoils, reaction, depth to lime, etc. Figure 3 shows how difficult it would be for a soil surveyor to locate the striking color changes in the soils which show so plainly in figure 1. With a set of pictures taken under uniformly good conditions the map will have a more uniform degree of accuracy than is possible if part of



Fig. 5—West Lafayette and Purdue University. Photo by U. S. Army Air Service.

the land is mapped when plowed as in figure 4 and part under heavy cover of corn, wheat, hay, etc.

In soil survey work the mapping of towns is often very costly of time and difficult to do accurately with plane table outfits. Figure 5 shows how plainly and accurately all the details of a town are outlined in aerial photos.

In strong contrast with the conditions of central Indiana is the limestone belt which is illustrated by figure 6. Here is an undulating plain, thickly dotted with sinkholes, some containing water as at A, and some dry as at B because of subterranean drainage. The road system is rather irregular because of the uneven topography. Several orchards



Fig. 6—Aerial photograph of limestone "sinkhole" country about five miles southwest of Bedford. Photo by Bowman Park Aero Co., of Louisville, Ky.

are to be seen and the bluffs along the White River are wooded. Around the "sinks" or "swallow holes" over most of the photo are numerous sharply etched areas where the "yellow clay" soil has eroded, but in the upper left-hand corner the smoother, almost blurred, appearance shows where sandy lands are found, while in the upper right-hand corner of the picture are overflow bottoms of the river.

Figure 7 shows an area lying along the state road between Bedford and Oolitic. The meanders of Salt Creek, railroad and race track are plainly shown. It is not obvious to the eye, however, that the race track is in a flat valley floor many feet below the rugged, wooded hills rising from the state road bridge across Salt Creek. In cases like this



Fig. 7—Aerial photograph of Salt Creek Valley between Bedford and Oolitic. Photo by Bowman Park Aero Co., Louisville, Ky.

the mirror stereoscope would be of great help in reading the photographs. This instrument is a simple device as shown in figure 8.

Through the courtesy of the Indiana State Highway Commission, we have obtained prints from the aerial photos taken in Martin and Lawrence counties. With them we have checked soil survey work already done in Lawrence County and have carried on experimental soil survey work in Martin County this fall. The results confirm our previous experience with photos taken by the U. S. Army Air Service at Purdue and prove to us the value and need of such pictures.

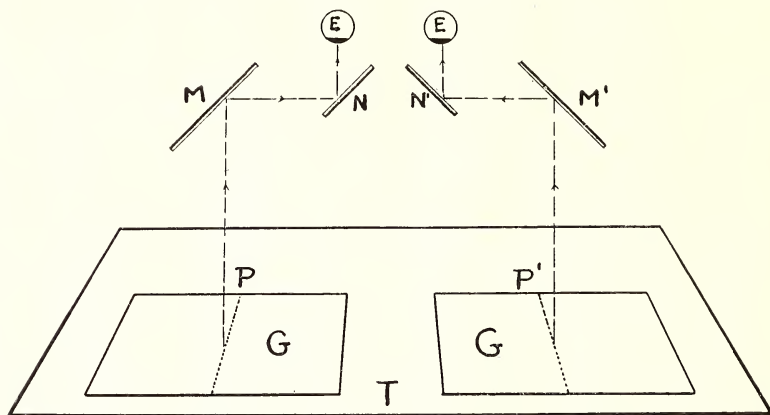


Fig. 8—Diagram of mirror stereoscope.

Two aerial pictures, P and P' , taken from viewpoints about one-half mile apart but with area G in both pictures representing the same land, are laid on a table, T . Their images in mirrors M and M' , (which are face down) are reflected to mirrors N and N' (which are face up) and thence to the eyes E E' of an observer. The pictures are moved on the table until the images of similar points coincide in the eyes, and stereoscopic vision of area G is attained.

As a matter of fact, definite study of the aerial photography question was begun several years ago and plans were matured to use the pictures in the soil survey of a whole county in the spring of 1927. The U. S. Bureau of Chemistry and Soils, with whom Purdue co-operates, requested the U. S. Army Air Service to photograph Rush County. Favorable action was expected on this request. However, the Mississippi flood conditions drew all available army planes away and in the meantime the federal board controlling policies of government aviation decided that the Army, Navy and Commerce air services "would do no work for anyone, including federal departments, until they had exhausted the resources and facilities of commercial aeroplane corporations." Proposals were then sent out and five firms bid on the Rush County job. The bids ranged from \$2,700 to \$9,000 for 409 square miles. As these all exceeded the funds available for such use, no bid could be accepted and the Army Air Service has again been requested to do this work.

The best season for pictures of this kind is in April and May when the trees are in leaf and when much land is plowed and no land is covered with heavy growth of crops. As pictures are taken from elevations of two or three miles, perfectly clear, cloudless days are necessary. A county can be mapped in about two days of actual flying. Army air survey charges were based on expenses of its men, flying expenses and cost of photographic materials. The estimate for these for Rush County was \$1,400. The Army Air Service carries all overhead, and has no selling costs like commercial firms. Commercial interests argue that our government has a broad policy not to compete with private industry and consider that making photos for government surveys is a legitimate field for private aerial photographers. Some other people have a theory that government economy demands that different departments should help each other out where it will save money for any tax-supported enterprise. The conflict between these two ideas is apparently one for the public at large and the authorities in high places to decide.

Soil survey is a relatively inexpensive kind of work and the cost of aerial photographs must be rather low if we are to use them. Specifications for any aerial photographic job may vary greatly, especially in regard to overlap, scale and total area to be mapped, so that the cost may vary from hundreds of dollars a square mile down to a very low figure. The value of pictures for some corporations may be very high, and merely as a matter of personal interest or curiosity all of us could pay as much for aerial pictures of our town or farm as we would for views of our house or face. When you consider that the ground photographer in safety snaps a view with a camera costing a few hundred dollars and note what he charges for his pictures, you will see that the aerial photographer, with a \$5,000 camera and a \$10,000 plane, risking life and limb two miles above terra firma, seldom over-charges for his product. Consider also that aerial photos of an entire county can be obtained for the cost of 500 feet of concrete road and they will not seem very expensive.

Soil survey can use the most inexpensive form of aerial photos—those with very little overlap—but in some cases it would be beneficial to have pictures, such as the engineers usually desire, which have greater overlap, so that we could use the mirror stereoscope. This is simply a system of four mirrors arranged so that a person can observe two overlapping pictures as one and obtain a vivid vision of the topographic variations. This overcomes the most disappointing feature of vertical pictures; namely, the monotonous flat appearance even in hilly country. Anyone looking straight down from an aeroplane has the same impression of a landscape.

We may expect in the future even higher standards of accuracy in all kinds of surveys. A set of aerial photos and good base maps made from them could serve a number of government surveys, such as topographic, geological and soil surveys, and aid in forestry studies, flood control and location of roads. Considering the enduring qualities of really good work and the economy due to large scale operations, the

complete aerial photographic survey would be the best possible foundation for different kinds of public work. In addition the negatives would be a photo library from which additional prints could be purchased by anyone at much less than the cost of the first set and thus be a saving and a service to the public in general. With pictures easily available, uses not thought of now would surely be found for them. The people of Indiana can well afford to make a thorough study of the possibilities of aerial photography, and facts already established should convince most people that a state aerial map would be practical, beneficial and fundamental to all kinds of surveys.

PERVERTED BENEVOLENCE AS AN INFLUENCE UPON RACIAL DEVELOPMENT.

GERARD FOWKE, Madison.

The most beautiful flowers adorning our parks and conservatories are evolved from coarser varieties only by intelligent cultivation, close attention, and unremitting care. If neglected, they soon revert to weeds, or suffer extermination beneath the rank growth of more vigorous common plants which will thrive in almost any place, and under the most untoward conditions.

If a florist wishes to create a new variety, he begins with a plant which is nearest the form he desires; he does not waste time in trying to change skunk cabbage into Easter lilies, or to obtain from bugbane the fragrance of heliotrope.

The farmer who wants to raise the best corn or wheat his lands are capable of producing will select from his crib or granary the largest and best-filled grains for seed; he has learned by experience that only thus can he expect to secure the most satisfactory returns for his labors.

Stock raisers know that beef cattle are not bred indiscriminately and fortuitously from pennyroyal scrubs, nor fine hogs from razor-backs, nor race horses from farm plugs.

In the various families of the animal and vegetable kingdoms Nature has established for each species a general average to which every individual specimen must closely conform. A plant or animal which falls below this plane is ruthlessly exterminated; one which by extraneous help or unusually favorable surroundings may rise above it, must return to its place when deprived of these adventitious aids. In process of time, under the influence of climatic or physiographic changes, evolution will gradually produce an alteration in structure: but development along such lines is practically uniform over a wide territory.

The practical truth of this general law has been impressed upon the farmer and the florist by a wide range of experience and by multitudes of failures. The lesson has been thoroughly learned by both, that if grain is to be prevented from retrograding to the grasses whence it is derived, or that if a garden is to be kept from reverting to a patch of weeds, incessant warfare must be maintained against the efforts of Nature to thwart the intentions of the cultivator. The veriest tyro will readily assent to the proposition, will deem it self-evident indeed, that a man who would devote the same care and attention to every plant, ornamental, beneficial or noxious, that found a foothold on his land; who would, for example, expend the same labor upon sedge as upon wheat, or would devote the same assiduous consideration to poison sumac that is required for bringing to perfection a tropical orchid, in the expectation or hope of obtaining products equally valuable or desirable from

whatever form of vegetation to which he would give his time and labor—that such a man is naturally and properly to be considered a fool.

And yet this is virtually the plan that is being followed in another direction by thousands of honest, earnest, well-meaning persons. They can not or will not see, or, plainly seeing, will yet persistently and vigorously refuse to admit that the human race is subject to the same laws which they readily acknowledge hold sway with the rest of animate nature. They waste time and labor in the vain endeavor to educate or civilize those who can not improve along the desired lines. Their motives are the best, and they are doing the kind of work necessary for the mental and moral elevation which must precede material progress.

Money is lavishly expended in maintaining all sorts of asylums, institutions, homes, refuges, and various other contrivances whose purpose is the alleviation of human misery, human dereliction, and human delinquency.

In our schools thousands of women drag a weary existence in the effort, too often vain, to “beat an education into young savages in spite of themselves”.

Missions are established in every part of the world for making rifts in the pall of darkness thick-hung over human brutishness.

Kind-hearted men and women spend their lives amidst most unpleasant surroundings, far from friends and kindred, often for many years beyond the reach of a congenial or sympathetic companion; they wear themselves out in discharging their self-imposed and too often thankless duties; they sink under the fatigues and hardships which make life a martyrdom and death a blessing.

High honor should be the reward of those who devote their lives to noble work; for, though masquerading among them may be found incompetents, hypocrites, reprobates, and mercenary time-servers, who assume a virtue to conceal a vice, yet such are only as camp followers in the ranks of noble men and women who bring to their task souls possessing in high degree the essence of spirituality which places them among the most worthy of our race.

But they are, for the most part, cultivating worthless or noxious forms of life. And to one who recognizes this, the respect he feels for their motives, much though it be, can not equal his regret for their lack of discernment.

It may be considered a matter over which it is worth while to make ostentatious parade, when, as a result of brain-wracking toil extending through months or even years, an idiot has been taught to distinguish one letter of the alphabet from another; or when, with equal exertion, a few individual members of some primitive or alien race have been induced to assent to certain religious formulas of whose meaning they have not the remotest conception; but what does all this amount to after it is done?

The amount of money wasted on attempted education of imbeciles, civilization of savages who are better off as they were created, and “culturization” of obstreperous barbarians and ruffians whose most urgent need is a whipping-post, would be sufficient to maintain schools for the free manual and technical education of multitudes of boys and girls

whose skilled labor would far more than recompense the community for its outlay. Yet, in the absence of such training, perhaps only a small percentage of these, even if all should remain honest and virtuous, could ever be anything but hewers of wood and drawers of water if condemned from childhood to unceasing toil with untrained hands and undisciplined minds. Our streets hold many Arabs, of either sex, born with decent instincts and fair abilities, who are literally driven into degradation and criminality by ignorance or dire poverty, their innate vitality or "will to live" prompting them to adopt any convenient or possible means of avoiding starvation.

In many instances we are making the mistake in our schools, especially in the public high schools, of giving to children of low mental caliber or deficient moral perception, a kind and degree of education which renders them totally averse to or disqualified from engaging in any sort of occupation for which they are fitted by natural endowments; or which enables them to be detrimental factors in commercial or professional life through acquiring a knowledge of facts and methods by means of which they may attain greater efficiency in applying their perverted business instincts, and avoiding legal responsibility for fraudulent actions or dealings. On the other hand, many a bright ingenious boy or girl is so hampered and repressed by official uniformity of method as to be unable in after life to make use of faculties which would enable them to attain to greater usefulness and happiness.

In every land beneath the sun there are thousands of valuable men and women whose entire energies must be devoted to the maintenance of themselves and their dependents and who have neither the time nor the strength left from this struggle to engage in higher work for which they are fitted. And of those who have risen from obscurity, whose energy and determination have made a name and a reputation for them despite all the adverse conditions by which they have been surrounded, how many might have surmounted still greater heights had they received judicious aid or encouragement that would have started them earlier on their career or allowed them to progress without interruption! Not all artists have painted; not all poets have written; and in science and mechanics the names of illustrious students to whom we owe great discoveries and inventions, are unquestionably fewer than could be contained in the lists of those who might have done as well if the path of progress had not been closed against them by poverty or lack of opportunities. It is no answer to say that "great spirits can not be subdued"; that "with equal energy any man may do what any other man has done"; daily observation disproves the assertion. Men of much natural ability waste their lives filling unsuitable stations into which necessity thrust them in youth and then barred all avenues to improvement. Others, less able perhaps but still possessing good brains, are forced to occupy positions much beneath their natural capacity, solely because they do not know how to do better or different work. Their powers become dormant through lack of proper training, and finally atrophy through disuse.

To be sure, in the demands and complexities of modern life there is to be found a vast amount of menial toil and drudgery; but let it devolve

upon those who can never be put to any better use. There is no danger that the supply of such will be exhausted as long as the present facilities for unrestricted miscellaneous propagation are allowed to continue.

The best method of increasing the happiness and welfare of a community would seem to consist in preparing young persons having capacity and ambition somewhat above the average, to take advantage of opportunities for advancing themselves and improving their condition; and in then presenting the opportunities. Whether this should be undertaken by the State or by the individual, it is quite certain that many expectations would be unrealized; there is no business enterprise which does not show items on the wrong side of a profit and loss account. But, at any rate, it is safe to say that the sum total of work accomplished in this manner would be of far more benefit and value to the world than all that can ever be produced by mental or moral cripples or inferior races who are incompetent at best, who progress only so long as they are pulled or pushed, and who relapse into pauperism, imbecility, barbarism, or crime, as soon as they are left to rely upon their own unaided efforts.

"The snake that sloughs comes out a snake again."

We condemn extravagant display and ostentatious living; but may it not be better to expend superfluous wealth on luxurious pleasures if thereby clean, respectable artisans or tradesmen can devote their talents to producing beautiful work, or to use it in paying sufficient salaries, than it would be to give a similar amount to idlers and incompetents, with no better result than that of enabling them to maintain their worthless legions?

One of the greatest hindrances to an abatement of crime and misery is this same indiscriminate charity. Many of our philanthropic efforts might well be called, "Devices for the Promotion of Mendicity and Mendacity". At all times, to be sure, there are in the world thousands, even millions, of worthy poor who are such by force of circumstances not within their power to alter, and who are entitled to sympathy and all necessary assistance; but there are other millions of degenerates, moral imbeciles, mental dwarfs, and natural criminals, whose deplorable deficiencies can never, under any state of affairs, be improved to a degree justifying any considerable self-sacrifice on the part of others. They are the useless survivors into modern times, of prehistoric conditions. They are the vermiform appendix of the body politic. If it be repugnant to our sense of duty to destroy them, there can certainly be no great reproach to us if we neglect to interpose an obstacle when natural causes are striving to abolish them, in order to replace them with something better; or if we decline to thwart the evident attempt of evolutionary processes at letting them gradually and painlessly become extinct.

Moreover, our benevolence, so far from alleviating the misery of such defectives, taken as a mass, is continually adding to it by encouraging them to increase and multiply the number of vicious and worthless weaklings who must always have a certain amount of extraneous support, careless whether the dole be obtained by beggary or by thievery. The small quantum of prudence which would prompt a

restraint of appetites and passions by causing the lower strata of humanity to reflect upon the consequences of their recklessness, improvidence, or wrong behavior, is scattered to the winds by the knowledge that no matter what may be the causes leading to pauperism and helplessness, the community—meaning thereby the self-respecting and careful who look out for their own futures—will be compelled either by law or public sentiment to give up so much of their earnings as may be demanded, to support in idleness the drones who have deliberately refused to provide for themselves.

The active exercise of emotional philanthropy is a direct violation of natural law; consequently, it is unwise, and deleterious to the best interests of humanity. All desultory, unsystematic, hit-or-miss efforts at amelioration of wretchedness defeat their own purpose, by recruiting the ranks of those demanding charity. The specious argument that it is our "duty" to overcome and repress any promptings of reason or judgment which would lead us to question the judiciousness of such exuberance of charity, furnishes its own refutation when carried to a logical conclusion. The thrifty and provident also have "rights", which are infringed upon when their property is taken from them for such purpose.

With the first manifestation of mobile life, in the formless speck of protoplasm, begins the work of eliminating the weaker and the less perfect; and through all stages of animate existence this process continues with constantly increasing force until the point is reached, among the higher classes of the human race, where the refinement of spiritual feeling leads to a protest against cruelty, and rebels at the seeming injustice which is the cause of so much suffering. We then attempt to "improve Nature"; and, of course, make a botch of our job.

The Arabs have a legend to the effect that when Jonah had emerged from his cetacean retirement and was on the high road once more, he saw a blind man by the wayside. He besought Allah to allow him to restore the poor fellow's sight. For some time, Allah demurred; but wearying at last of importunity, gave the desired permission. As soon as the beggar got his bearings, he began throwing date seeds at Jonah, who felt the sting quite keenly, his skin being still soft and tender as a result of its prolonged and unaccustomed exposure to warm fluids. "How is this, O, Allah?" he exclaimed. "I treated this man with kindness and he repays me with injury." "You could not be content to leave matters as I had arranged them," replied Allah, "so now you must accept the consequences of interfering in affairs which are none of your business."

In the nations which by centuries of selection and improvement have gained a commanding position in the world, there are numerous individuals so unconscious of the obvious causes by which this condition has been brought about, as to believe in the psychic equality of all their fellow-beings. They regard the emotions and motives of depraved and criminal men and women from the standpoint of highest Christianity. They imagine that bestial, cruel, undeveloped, or mal-developed wretches, in whatever grade of human existence, dwelling by preference in purlieus of vice and filth, or like wild beasts in desert or forest, will forsake their

chosen life and at least make an attempt to become mild in manner and refined in tastes when told it is their "duty" to do so. If these worthy and conscientious promoters of righteousness had a more accurate knowledge of human nature, if they would mingle more freely and familiarly with the objects of their solicitude, they would comprehend the futility of their endeavors. The moral development of mankind, taken as a whole, proceeds in its earlier stages almost as slowly as the physical development; and it is only by centuries of self-striving and self-help, even after their eyes are opened to a knowledge of good and evil, that the best elements of a race or a people can attain to a high standard of excellence. The inferior types remain at varying depths beneath; in the most civilized centers the ape-and-tiger instinct is perniciously active, and sometimes finds its victims among the purest and noblest because these so frequently commiserate instead of condemning the depraved and vicious.

It can not be too often repeated or too firmly impressed that always and everywhere cultivation implies, nay, demands, extermination. Wolves and lambs, tigers and gazelles, can not be reared together; we can not raise a crop of corn and a crop of weeds on the same ground in the same year, and have two good crops. In regard to animals and plants alike, the choice lies before us, "Which shall be preserved?" Such a question seems too trivial to formulate; and yet the analogy between it and the question, "Which is the better, a respectable citizen, or an irreclaimable thief, or ruffian, or pauper?" is perfectly clear.

We are all agreed that the weeds and the beasts of prey must go. If it be impracticable or impossible, at present, to eradicate the congeners of the weeds and the beasts from the human race, they should at least be rigorously excluded from the areas where cultivation is in progress. They must all die in the end, anyhow; and if we grow pathetic over the extinction of delinquents, defectives, even of a tribe or a whole race of primitive men who can not, or will not, keep step with the progress of enlightened peoples, let us endeavor to explain to ourselves the wisdom or the utility of worrying over the fate of future generations which have not yet been, and from the very nature of the case never can be, brought into existence?

We deem it our duty to bend every effort toward the extermination of animals and plants hurtful to us through their own volition or the possession of some noxious quality; we wage unceasing strife against those which, though harmless in themselves, yet militate against our endeavors to produce what is of use to us; but we spend our time and our strength, our money and our lives, in the attempt to preserve as long and in as great numbers as can be done, the degraded and criminal types of the human race which are a constant menace to health and property and progress.

We make them shiftless, indolent, and worthless, because we teach them they will always be cared for, no matter how little they deserve it. We make them deceitful, sneaking and treacherous, by the facilities we afford them for preying on our kindness. We permit them, or even encourage them, to marry when scarcely adolescent, and the conditions of the life they lead are so favorable for unstinted propagation that they

multiply in far larger ratio than do those who are struggling upward in the scale of life, until the children almost seem to come in litters; and these, with their birthmark of undesirable mental traits or physical imperfections, we sedulously care for, to poison and corrupt the blood of future generations, like a fungus engrafted on a healthy vine.

Striving for a bulky census roll, we seem turgescient with pride and satisfaction as we contemplate our increase of population, regardless of the fact that too much of it is due to the annual accretion of these mill-stones about our necks.

We have the appearance of congratulating ourselves on the growing army of neurotics, imbeciles, paupers, incorrigibles, and criminals, who crowd our public institutions as fast as they can be erected.

We complacently make annual reports of the numbers thus provided for, the vast sums of money expended, as evidence of our wealth and culture, of our ability to keep in the front ranks of civilized nations; in which respect we may be compared with a Marathon runner who would triumphantly display a patch of sticking plaster over an abscess in his hip as a proof of his qualifications for entering the race and his superiority to contestants who were less careful in treating their disabilities.

We tax the resources of Church and State to provide means for the still further increase of places of refuge or detention; we so conduct our economic, political, social, religious, and charitable organizations as to keep these asylums and penal institutions crowded to their capacity, with a constantly increasing demand for more room. Yet, with illogical sentimentality, we so frame our laws as to set at liberty many of those most capable of mischief.

In a word, we are trying to preserve the weeds at the expense of the flowers, and are vainly hoping that under such treatment all will soon be flowers alike; losing sight of the fact that there is no method of securing uniformity of elevation except by leveling downward; that to level from below upward is an impossibility, whether in mind or matter.

It is well to bear always in mind that "Nature cares nothing for the individual, but everything for the species"; and that the species is perpetuated by getting rid of the least progressive individuals. We, wiser than Allah, seem desirous of reversing the process.

Well, "we are a great nation." It may work out all right. But the man who persistently demands of his physical organization that it assimilate large quantities of unwholesome food, often lives to wish he had not been such a fool; and a nation is only an aggregation of men.

There is a glimmer of light in the horizon. For generations, not satisfied with our own great and steadily increasing production along these lines, we have allowed or even encouraged reinforcements from other lands. Now, we are trying to put up a fence to keep out the "undesirable foreign element." Is it too much to hope that, in time, we may awake to the propriety of confining by some sort of barrier, the scum and dregs which are with us to stay because we have no place to which we can send them? The remedy is simple and practical; merely, by segregation or otherwise, to prevent their further breeding.

A PLEA FOR JOHN R. KISSINGER.

R. A. GANTZ, Ball Teachers College.

John Kissinger enlisted in the Indiana National Guard July 28, 1897, and became a member of Company D, the 157th Indiana Volunteer of United States Army, May 10, 1898. He was discharged November 1, 1898. On November 15, 1898, he enlisted in the Hospital Corps, U. S. A., and was discharged November 14, 1901.

When the United States occupied Cuba, a commission of medical officers including Doctors Reed, Carroll, Lazear and Agramonta, was sent to find out the means by which yellow fever is transmitted. The work of these medical officers is known in a general way. But little is known of the first volunteer who permitted female mosquitoes of the genus *Stegomyia* to bite him. This person is John R. Kissinger, now living at Huntington, Indiana, R. R. 8. With a class in public health, I visited his home on this November 5, where he told us about that human experiment which resulted in the gradual restriction and control of yellow fever.

Mosquitoes which had bitten yellow fever patients were permitted to bite Kissinger. In a few days he came down with a chill. The first forenoon he felt fairly well but did not get up. At 4 p. m. he became worse with a fever of 102 which remained constant. When delirious, Doctor Reed fed 120 mosquitoes on his body.

With efficient nursing and constant care of Doctor Reed, Kissinger seemingly recovered. While yet sick many visiting surgeons came and studied his case. His tent became a clinic. After he had gained strength, the doctors injected into his body, blood from yellow fever patients to see if he were immune. John Kissinger feels that his body probably would have come through successfully had he been subjected only to the disease.

In 1906, he became helpless and for the past 21 years has not been able to do any kind of work to earn wages. He fought against the pension when health failed; he did not give in his record. Through efforts of his wife and friends, information was given and he was called before the pension board.

In 1911, the government granted him a pension of \$100 per month. This has been their only support. They, needless to say, have not been able to save anything. He made two attempts to buy property but failed. Before coming to Huntington, he and his family lived at South Bend, Ind., Homer, Mich., and Anderson, Ind. Since June, 1927, they have lived at Huntington, in a house bought and presented to them by a fund raised through the efforts of Prof. James E. Peabody, of New York, and the American Association of Medical Progress, New York City.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

The upkeep of this modern home takes a little more of the \$100 per month than did the upkeep of a rented one. This man has the minimum amount of bread and butter at the hands of our government to whom he gave himself that others might not have yellow fever. A bill was introduced in the House of Representatives during the sixty-ninth Congress for the relief of Mrs. Lazear, Carroll and Reed, and John Kissinger. Do we not owe it to our neighbor and co-worker in science to inform our congressmen whom we might know, as to the neglect and need of John R. Kissinger?

MAKING BIBLIOGRAPHIES MORE USEFUL.

M. G. MELLON, Purdue University.

During the course of each year there are published a large number of bibliographies as a part of journal articles, public documents, sections or chapters of books, and similar publications. An examination of these bibliographies reveals a wide variation in their usefulness due to the kind of data included or to the arrangement used, or to both. An outstanding example of a poor publication of this type may be found in a bibliography of over 400 pages, including hundreds of entries, published by one of our national societies. Because of the manner of its compilation, very much of the possible usefulness of this collection of facts is practically lost, although much time and considerable expense was required for making it.

Since individuals writing articles or books, or directing the preparation of theses, can greatly increase the value of many of the accompanying bibliographies by devoting a little more attention to such compilations, it seems desirable to consider briefly some of the bibliographic forms, together with the information that may be included in them, with the ultimate intention of advocating the compilation of bibliographical facts in a manner suitable for their most efficient use.

For the purpose of the present discussion a bibliography may be defined as a list of references relating to a given subject or to the works of a given author. In a chemical bibliography these references relate to any or all of the following sources of information: periodicals, public documents, patents, dissertations, manufacturer's technical bulletins, and books of various kinds.

Information Included. In the usual bibliography part or all of the following information is given for each entry: author's name; title of publication; some statement, in addition to the title, indicating the exact location in the publication of the material cited—the latter includes for a book the volume, page, and year (or number of the edition); for a patent, the name of the country issuing the patent, the number, and the date; for a public document, the name of the division issuing the document, together with proper designation, number and date; and for a journal article, the title of the article, series, volume, page, and year—and an annotation indicating the nature of the material to be found in the source to which reference is made. If the bibliography is a separate publication, preferably all of the above information should be included. If it is a part of a book, often the author's name, together with some statement regarding the contents, occurs in the body of the discussion. Annotations are the exception except in separately published bibliog-

raphies. Regardless of the part of the above data included for a given entry, whatever is given is usually spoken of as a reference.

Whatever data is given for the reference or citation, it should indicate unmistakably the essential points of those mentioned above, such as volumes and pages; but, at the same time, it should be as brief as possible in the interest of efficiency in reading, proof reading, writing, and preventing error. Unfortunately, the literature of chemistry abounds in annoying examples of digression from this general principle. As instances of this kind, one needs mention only such things as the use of Roman numerals, the inclusion of the number of the issue for the ordinary chemical journal, the omission of the year, or more serious yet, the omission of the series. It is a matter not only of confusion in the older literature, but also of lack of uniformity in present practice. There are still many writers who disregard the excellent procedure followed by the editors of Chemical Abstracts. As an example of what is still happening in scientific publications two citations are quoted from a recent article,¹ calling attention to some desirable reforms. These two refer to the same article but appeared in different periodicals: (1) *Ann. Appl. Biol.*, (24 [1923], No. 2, pp. 151-193, pls. 3, figs. 31); and (2) *Ann. Appl. Biol.* 24: 151-193, 3 pl. 31 fig. 1923. The second contains 16 less characters but without sacrificing anything in essential information.

Arrangement. A bibliography is essentially only a list of references, with no specification regarding the arrangement of the separate entries in the list. Although a list not systematically arranged is to be preferred to none at all, the advantages resulting from the adoption of a definite order are well worth the extra time and effort required to put the references in this form. For most bibliographies one of the following schemes may be followed in listing references:

1. According to the order in which the references are mentioned in the text. Although this scheme is used in some important works of reference² and in many scientific papers, one must ordinarily read more or less of the accompanying discussion in order to obtain the significance of any given citation. Each entry generally includes the name of the author and data for locating the material to which reference is made.

2. Alphabetically according to the name or title of the publication containing the contribution. This is one of the least satisfactory schemes, but it may be used when the author's name is omitted.

3. Chronologically. This scheme may be desirable in some cases, especially if the time of publication of the contributions is an important point. It serves also to indicate the historical development of the subject. The various references occurring under the same year may be given a serial number.³ They may also be arranged alphabetically by authors under each year.⁴

4. Alphabetically by authors. This is the most used system, and,

¹ *Science*, 62, 419 (1925).

² Mellor—*Comprehensive Treatise on Inorganic and Theoretical Chemistry*. Abegg—*Handbuch der Anorganischen Chemie*.

³ Howe—*Smithsonian Pub. No. 1084—Metals of the Platinum Group*.

⁴ West—*Vitreous Enameling of Iron and Steel*.

in the opinion of the author, it is the best for most purposes. The following three variations in this kind of arrangement may be mentioned:

(a) A simple alphabetical list is made, with or without a serial number for each entry. This is satisfactory for short lists but not when the number of entries is large,⁵ since too much time is then required to ascertain whether a reference to some specific point is included.

(b) The arrangement is the same as in (a), including the serial number, but with the addition of a comprehensive subject index. The latter is prepared on the basis of the material contained in each entry and so arranged that the numbers under any given subject in the index indicate the serial numbers of the references in which this subject is treated.⁶

(c) The references are first classified, some procedure such as the following being used: according to the nature of the publication in which the references occur, as periodicals, public documents, patents, and books; according to some special view points of the author; or according to the natural subdivisions or particular phases of the subject with which they deal. They are then arranged alphabetically in each of these divisions. As in (a), they may or may not be numbered.

The following classification used by Schrero in his bibliography on water glass illustrates the advantage of this system:

Bibliography	Applications—(Cont.)
Patent literature	Glass and ceramics
History	Medicine and surgery
General	Paper
Properties	Structural materials
Manufacture	General and miscellaneous
Applications	Artificial stone
General and miscellaneous	Concrete
Agglutinants	Fireproofing-preservation of wood
General and miscellaneous	Paints and preservative coatings
Abrasives	Textiles
Cements	
Detergents	
Analysis	
Egg preservation	Analysis

For general, and more or less extensive, bibliographies the arrangements mentioned in 4b and 4c seem the most useful, particularly if annotations are included. In locating, for example, the references dealing with the corrosion of copper alloys in a general bibliography on corrosion, one would turn in the former case directly to the index and look for the words alloy and copper. In the latter case it would be necessary to locate the division dealing with copper alloys. Probably in most cases an individual using such a bibliography wants information only for special purposes and consequently is not interested in reading

⁵ Branner—A Bibliography on Clays and the Ceramic Arts.

⁶ Van Patten—Bibliography on Corrosion. West and Gilman—Organomagnesium Compounds in Synthetic Chemistry.

through even 50 articles to find that the valuable material is contained in some three or four which might have been immediately evident in a well arranged bibliography. If the list has no such arrangement, he must examine all references given in order to select the desired ones, or to assure himself that there are none of value included.

NATURE GUIDING AT TURKEY RUN STATE PARK.

SIDNEY R. ESTEN, Department of Conservation.

Nature movements have been progressing in Indiana for a number of years. The Nature Study Club of Indiana, the State Audubon Society, various bird clubs and a number of local nature study clubs have been doing excellent work in fostering the study of natural history.

One of the most recent innovations in nature study in the state has been the work of nature guides and the organization of silent and test nature trails in state parks. For several years Miss Lucy Pitschler has been guiding visitors at McCormick's Creek State Park and pointing out various interesting objects of nature along the trails. During the past summer Miss Pitschler not only conducted nature trips at Clifty Falls State Park but also had a silent nature trail. The same kind of nature work was done at McCormick's Creek State Park last summer by Mr. Brandt Steele.

During the last year Dr. Earl Brooks laid out a silent nature trail in the city park of Noblesville and Dr. L. A. Test made a similar trail at Winona Lake.

Under the direction of Captain Charles Sauers of the Department of Conservation an experiment in nature study was conducted at Turkey Run State Park. This experiment was conducted by Mr. and Mrs. Sidney R. Esten of Pendleton, Indiana, Otto Behrens, Jr., of Anderson, and Frederick Test of Lafayette, who were at the park from June 20 to September 7, 1927. The underlying principles of the nature work as organized and conducted at Turkey Run were a combination from two other movements—one national and one state in origin—and other plans were formed as the need became apparent.

At the Yosemite National Park in 1920 a free nature guide service was offered, under the direction of Mr. Stephen T. Mather, Director of National Park Service. This service has become so popular that each year it has been enlarged until today there are nature guides in all the larger national parks. About the same year, 1920, nature guide service was introduced in the east at the Harriman State Park in the highlands of the Hudson River of New York. There, under the direction of Major W. A. Welch and the supervision of Miss Ruby M. Jolliffe in boys' and girls' camps, some systematic work was carried out under trained leaders. At the same park in 1925 Dr. Frank E. Lutz laid out the first silent and test trails where labels with information and others asking questions were used. This form of nature work proved to create such a great interest on the part of the general public that today there are about 200 silent trails in the United States, all modeled after the "Mother Trail" made by Dr. Lutz.

At Turkey Run it has been the aim to use both parts of the nature program, the guiding feature and the silent trail, and then to add other

features which are well adapted to Turkey Run. The program of the park consisted of seven main parts as follows:

1. A study of the flora and fauna of the park; 2. Nature hikes;
3. Bird hikes; 4. Silent trail; 5. Test trail; 6. Nature museum;
7. Lecture program.

The following is a more detailed account of the seven parts of the work with a list of the objects of nature studied.

1. Study of the flora and fauna of the park.—In studying the flora and fauna of the park during the two and one-half months many interesting plants and animals were listed. It was the task of the nature guides to make a compiled list, using the results of many specialists in their respective fields as well as the direct work of the guides themselves. The list follows:

Animals: 4 species of salamanders, 2 frogs, 2 toads, 11 snakes, 3 turtles, 1 lizard, 6 fish, 75 summer birds and 15 mammals.

Plants: 10 species of lichens, 55 mushrooms, 41 mosses, 8 liverworts, 19 ferns, 1 club moss, 2 horse tails, 200 flowering plants other than woody plants, and 100 species of woody plants.

The total number of animals.....	119
The total number of plants.....	496

The total number of forms of life.....	615
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2. Nature hikes.—Nature hikes for visitors left the hotel each day at 8:15 a. m. and 2:00 p. m. under the leadership of one of the guides. The object of these hikes was to introduce visitors of the park to the mushrooms, lichens, mosses, ferns, flowers, trees, birds, animals and other forms of life found in the park. A total of 117 regular trips were conducted with 2,322 people taking advantage of this method of nature study. During the summer 501 people, representing nature classes, convention groups and special parties, were taken on 30 special hikes.

3. Bird hikes.—Three times a week from 5 a. m. to 7 a. m. bird hikes were taken. A total of 21 hikes were taken for 194 visitors and the average number of birds seen each trip was 30.

4. Silent trail.—Trail 1 from the hotel along the river east to the swinging bridge, up the stairs to the roadway, and west along the road to the hotel was selected as the silent trail. On this trail, which was a mile in length, No. 5c Denison linen tags were used on objects of natural interest. Not only the common and scientific names of the trees, flowers, mosses, fungi and lichens were put on the tags which were attached to these objects along the trail but also interesting information relative to the plants was placed on the tags. The geological history of the park, Indian legends, general information and conservation lessons were also put on these tags. Three hundred twenty-six labeled tags were used along this trail and it was carefully estimated that about 30,000 people took advantage of these labels to get better acquainted with nature.

5. **The Test trail.**—A trail five-eighths of a mile in length was selected as the test trail. This trail started at the north side of the swinging bridge and followed Trail 4 up Rocky Hollow, then Trail 3 for a short distance west, south along the top of the bluff, through wooded areas to Trail 3 again and east along the creek to the swinging bridge. Upon this trail about 100 descriptive tags were placed on interesting objects of nature not found on the silent trail. Then 55 tags with questions were placed along the trail on objects previously labeled and described on the silent trail. Any one desiring to test his knowledge of nature could write out answers to the questions and bring them in for correction. A blue card giving membership in the Turkey Run State Park Nature Trail Club was issued to all who passed a grade of 75 per cent. Much interest was shown on this trail by adults but more interest was aroused in boy and girl scouts and nature students.

6. **Nature museum.**—The state cabin at Sunset Point which was built about 1841 and which contains huge tulip tree logs, was used as the museum. It also contains a number of relics of pioneer days. This cabin was open to the public every afternoon and also in the mornings on Sundays and holidays. The aim of this museum was to give visitors a knowledge of the plants and animals which could be found in the park. Pictures of many of the flowers and of the summer birds were exhibited. In co-operation with Mr. Frank B. Wade of Indianapolis, about 40 geological specimens of the park were collected and placed in the museum. A few specimens of fossils, fungi, mosses, lichens, shells, cocoons, liverworts, and galls were placed there. A bird nest collection of eight nests was started. A collection of about 150 insects was made as a beginning of a much larger collection next year. Several living specimens of salamanders, lizards, and snakes were put into the museum. Preserved specimens of snakes were assembled to show all the kinds found at the park. In all, during the summer about 300 pictures and objects of nature were placed in this museum. The collection was limited in size because of the lack of space and limitation of cases for specimens. It is hoped that next summer the museum will be better organized with more space and better facilities for exhibiting to visitors the interesting objects of nature found at Turkey Run. During the summer 19,919 people visited the museum.

7. **Lecture program.**—Illustrated lectures were given on four nights a week in the sun parlor of the hotel. These lectures—a series of ten in number with four on summer birds of Turkey Run, two on conservation, two on forestry, one on insects and one on flowers—were given to all visitors of the park who cared to attend. For the first weeks the attendance averaged 30 people to each lecture but during the later part of the summer the average was about 75. During the summer 43 lectures were given as follows:

Fred Test	6 lectures
Otto Behrens, Jr.	6 lectures
S. R. Esten	31 lectures

The total attendance for this series was 2,550 or an average of 59 to a lecture.

For the summer of 1928 nature guiding will probably be even more popular than last summer. The labeled trails laid out last summer were only temporary but the aim of the future is toward metal tags which will remain up winter and summer and will be of value to visitors of other seasons of the year than just a few weeks of the summer. The numbers of plants and animals listed will increase, for the lists to date are only partial. The next few years will see a perfecting and enlarging of nature trails and nature guiding, not only at Turkey Run and other state parks but also in connection with local and county parks, with schools and colleges, scout camps and other organizations.

COPPER NUGGET FOUND AT TURKEY RUN.

SIDNEY R. ESTEN, Department of Conservation.

On August 23, 1927, while gathering geological specimens with Mr. Frank B. Wade of Indianapolis, for the Turkey Run State Park Museum, we found this nugget of copper. It was found among the glacial drift about one-half mile up Boulder Canyon. It is irregular in shape, measuring two inches in length, one and one-half inches wide at one end, one inch wide at the other, five-eighths of an inch thru the thickest part and the weight is 105.2 grams.

THEORY OF THUNDERSTORMS.

DANIEL HULL, University of Notre Dame.

The fundamental principle involved in this theory is the following: A thunderstorm is impossible till the top of the cloud is frozen, which may be extended to: No actual rain or snowfall is possible till the top of the cloud is frozen.

Figure 1 shows successive stages of growth of a typical summer cloud observed near the horizon under favorable conditions of temperature and pressure for a rapid growth. Air sultry, barometer falling.

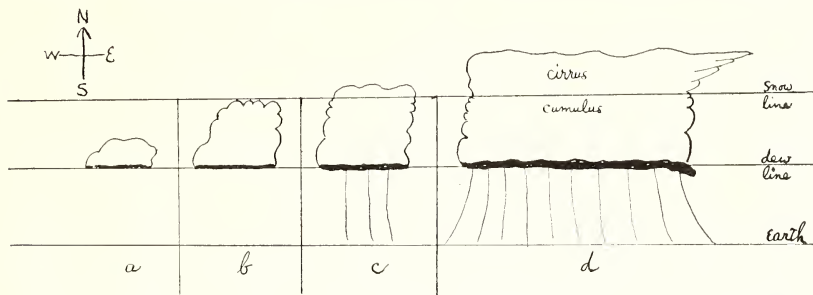


Fig. 1—Growth of a typical summer cloud: *a*, about 9:00 or 10:00 a.m.; *b*, cumulus, an hour or so later; *c*, nimbus, towards noon when its top has risen above the snowline and precipitation has commenced; *d*, early afternoon when thunderstorm has developed. Note that the nearer the cloud top to snow line, the sharper the curl and above the snow line this "curl" fades into cirrus.

At the dew line, the water vapor in the air condenses and becomes visible as fog (cloud) in a slowly rising air column. This cloud is made up of minute globules of water, each surrounding a tiny dust-speck as nucleus. This dust-speck, terrestrial rather than cosmic, is carrying a minute charge of static electricity acquired when leaving the earth's surface under the influence of wind.

Figure 1, *a* and *b*, shows this mass of water dust rising to the snow line. So long as this cloud remains below the snow line, there can be no precipitation, no electrical display, because the billions of water globules are carrying similar charges and all repelling one another. This gives rise to the curly top appearance of the cloud usually known as "thunder heads". But, let the rising air column carry this cloud top above the snow line (fig. 1, *c* and *d*), and, presto, these globules are instantly converted into myriads of pointed ice crystals, and their static charges are collected from point to point of these crystals and accumulated in the frozen top of the cloud till the potential difference between this total charge, so accumulated, and the earth may be sufficient to cause a neutralizing spark to pass from cloud top to earth (chain lightning).

If the cloud top is not rising fast enough, the intervening moist air between cloud top and earth may act as conductor for a silent (brush) discharge of electricity. This happens with light gentle rain or snow-fall, whereas the faster the cloud top is rising, the heavier the rain or hailfall and the more frequent and stronger are the "sparks" of lightning.

If the uprising air column in this cloud (nimbus) is rising faster, like the draft in a high chimney, the storm becomes more violent in precipitation, electrical display and air disturbance (wind). The extreme case giving rise to rotation about the up-draft. This type of thunderstorm is the dreaded tornado.

We see then, that, as long as the cloud is between dew line and snow line, nothing happens except a strikingly beautiful "cumulus" cloud—a bunch of water dust—a vast electrical condenser, carrying its charge on the surfaces of its myriad spheres and with no way to discharge this; but once above the snow line, the spheres become pointed crystals and their charges collect by streaming off the crystal points, leaving these crystals to freeze into small groups, called snowflakes, which presently have sufficient mass to fall, some below the snow line where they are coated with ice by coming in contact with the "water dust" of the cumulus part of the cloud. If, as frequently happens, this sleet is again carried in the uprushing air column in this nimbus, above the snow line, it becomes coated with ice crystals and heavy enough to again fall, possibly to earth, as a hailstone, or, as usually happens between dew line and earth, it melts and falls as a rain drop, growing as it falls through the humid air.

The interior of hailstones shows invariably a snowy white nucleus surrounded by concentric shells of clear ice alternating with a whiter snowy layer, each one of these bearing witness to a trip back above the snow line where the snowy layer was formed. Therefore, we conclude that the larger the hailstones so formed (not aggregated) the more severe the storm, because the stronger the uprising air column in this nimbus.

With rare exceptions, lightning in passing between cloud top and earth follows the belt of rainfall because these drops grow in falling and so acquire charges from smaller globules till overcharged, this overcharge helping the potential difference causing the spark.

At some future time, I should like to explain why this theory was developed by constant observation during 40 or more years in different parts of the United States, Canada and Mexico—apparently different conditions always giving rise to the same phenomena, always pointing invariably to the text of this article: A thunderstorm is possible only when the top of the cloud is frozen, and why.

THE DISTRIBUTION OF PRECIPITATION IN RELATION TO THE MISSISSIPPI BASIN FLOODS OF 1927.¹

J. E. SWITZER, Indiana University.

From the time Noah built the Ark and saved his family and a family each of all the fowls of the air, of the beasts of the field, and of every creeping thing, history has been replete with records of man struggling to prevent the waters of the deep from encompassing him.

In nearly all river valleys of the world, periodic floods are more or less frequent. In 1913 a record-breaking flood spread over the Ohio River Basin and extended into the lower basin of the Mississippi River. The year 1922 was another notable flood period but 1927 broke all previous high water records in the lower Mississippi and in many of its tributaries. The question of how to prevent the recurrence of such a disaster has been, and is, occupying the minds of the people. Legislative committees of the National Congress have been busy for weeks working on possible legislation to aid in flood control. Numerous and varied are the recommendations proposed. The states of the west are asking for reservoirs to store the storm waters in their territory and furnish water for irrigation and at the same time aid in flood prevention. The farmers along the Mississippi River are asking for stronger and higher levees to permit them to cultivate in safety the rich bottom lands.

To plan an adequate flood prevention program, it is necessary first of all to determine the causes of the flood conditions. It was in an attempt to discover the relation of the distribution of precipitation to the flood conditions that this study was begun. This paper confines itself to the particular conditions of the Mississippi Basin floods of 1927.

The floods of 1927 may be said to have had their beginning in the late summer of 1926. The precipitation of August, 1926, exceeded the normal precipitation for August in nearly all of the Mississippi drainage basin lying east of the river and in most of Missouri, Arkansas, and Louisiana west of the river. In the southern parts of Indiana and Illinois, in most of Kentucky, and in parts of northwestern Tennessee the excess was over four inches, reaching over six inches in the extreme lower part of the Ohio drainage area. From 60 per cent to 80 per cent of this heavy precipitation occurred from August 12 to 25. The Ohio River formed about the central axis of the belt of heaviest precipitation, hence there resulted a rapid rise in the Ohio, which, at Louisville, began

¹The chief sources of information for this paper are the Climatological Data by Sections, the Monthly Weather Review and the Daily Weather Maps. Unpublished blue print data of river stages were furnished by the Mississippi River Commission, and personal letters were received from a score of U. S. Weather Bureau Section Directors in the Mississippi drainage area. To all these men grateful recognition is due.

on August 16 and reached its peak August 25, a rise of 27 feet. At Cairo, a crest with a 19-foot rise, occurred on August 30.

The beginning of high water in August was followed in an area extending from Oklahoma and Texas to Pennsylvania, and from the Ohio River to the Great Lakes by one of the rainiest Septembers on record. (Fig. 1.) For Kansas it was the wettest month in three years. The eastern part of the state averaged from four to eight inches above normal² the precipitation occurring mainly in three periods of excessive rains on Sept. 3 to 5, 12 to 15, and 26 to 30.

In Missouri, it was the wettest September on record, and has been exceeded but three times in 56 years by the precipitation of any month.³ In the northeast plain, drainage directly into the Mississippi and lower Missouri, there were but six days that were generally without rain during the month. Thirty-three stations reported over 10 inches for the month, while one reported 18 inches.

The precipitation of Oklahoma was more than double the normal, occurring chiefly in three periods like that of Missouri. One station reported 7.8 inches falling in 24 hours, while 35 other stations reported over 2.5 inches during the same length of time.

In Iowa, the rainfall record exceeded by one inch that of any month during the 56 years of record.⁴ Heavy downpours were general, especially on Sept. 1, 8, 18 and 19, when 88 station reports gave over two inches in 24 hours.

Illinois had the wettest month, both in terms of the number of rainy days and in the total amount since 1879. It likewise was noted for widespread periods of heavy downpours in 24 hour periods, reaching as much as 6.43 inches.⁵

Indiana and Ohio had the wettest month for which records have been kept. For Indiana, it was two and one-half times the normal for the month and well distributed. The farmers chafed under these wet weather conditions that caused their grain to remain in the field and rot. Motorists rebelled at being held up by high water on the roadways, but little did either think that what they were enduring was but the prelude to the great drama to be enacted some months later in the unprecedented high waters of the lower Mississippi. However, had this area of excessive precipitation (fig. 1) been 100 miles farther south with the Ohio River forming the axis of the belt, there would probably have occurred at this time the greatest floods the Ohio River has ever known.

A word may not be amiss at this point in regard to the general weather conditions of the month. The outstanding facts were the pronounced "lows" that successively crossed the continent and developed into low troughs reaching from Texas to the Great Lakes, and even to the lower St. Lawrence Valley. The month was ushered in with a low center in the Montana-Dakota region and an extension of it southward to Texas. The northern part moved eastward, forming a long, low trough and carrying heavy precipitation to the Atlantic Coast. In the southern

² Climatological Data for Kansas, September, 1926.

³ Climatological Data for Missouri, September, 1926.

⁴ Climatological Data for Iowa, September, 1926.

⁵ Climatological Data for Illinois, September, 1926.

part of the trough, another low center developed which took four days to pass the Great Lakes as it slowly moved eastward. It was followed by a "high" which crossed the area in a day and in turn was followed by another low which developed into a long low trough where heavy precipitation occurred along the wind shift line. This sort of succession was repeated about every three or four days well into October and was responsible for the heavy precipitation of September, and that which continued into the following month.

The inevitable result of such widespread and unusual rains was the general high waters in the district. Disastrous floods occurred in the Floyd, Big Sioux, and Raccoon rivers of Iowa, following the especially heavy rains there Sept. 17 and 18. High water in the Illinois River began with the heavy rains of Aug. 31, which were followed with scarcely a break by those of September and early October, so that not until the last of November was the entire river out of flood stage.⁶ The Wabash River was in flood stage from Lafayette, southward. The soils were saturated, and heavy rains fell in short periods; i. e., at Terre Haute on Oct. 8-9, 5.16 inches of rain fell in 8 hours and 52 minutes. The river rose so rapidly that it was impossible for forecasts of the rise to be given.⁷ Nearly bank full stages occurred in the Missouri, but little actual flood conditions resulted. Two destructive floods occurred in the Grand River of Missouri, and a moderate one in the Osage. The Mississippi River was near flood stage from Quincy to the mouth of the Ohio River from early September to the last of October. The crest of this rise was reached at St. Louis about Oct. 20 and then gradually decreased there until the last of January. The lower Mississippi, fed by these bank-full tributaries, reached flood stage about the middle of October, then decreased during November. The Arkansas passed flood stage at Ft. Smith on Oct. 4 and Pine Bluff on Oct. 12.⁸ The Ohio River experienced rhythmic rise and fall but did not approach flood stage except near its mouth until the last of December, in spite of the fact that the State of Ohio has had but three wetter Octobers in 100 years, and that the Ohio River basin had a slight excess of precipitation for October throughout most of its area. It was not characterized, however, by the extreme downpours that were responsible for the flood conditions farther west.

The areas of excess precipitation in November were in the upper Mississippi and Missouri basins, and in the area south of the Ohio River and east of the Mississippi. This excess for the month was not large, but in the Cumberland and Tennessee river basins it occurred in the latter half of the month, and was followed in Tennessee by the wettest December on record. The average for the state was 10.69 inches, of which eight inches fell from Dec. 20 to 28, inclusive. On Dec. 21, 21 stations reported over three inches fall, seven of these reporting over five inches in 24 hours. In the Tennessee basin of northern Alabama the precipitation for the month ranged from 10 to 15 inches, occurring

⁶ Mo. Weather Rev. vol. 54, p. 401. Sept., 1926.

⁷ Mo. Weather Rev. vol. 54, p. 443-445. Oct., 1926.

⁸ Climatological Data, Arkansas. Oct., 1926.

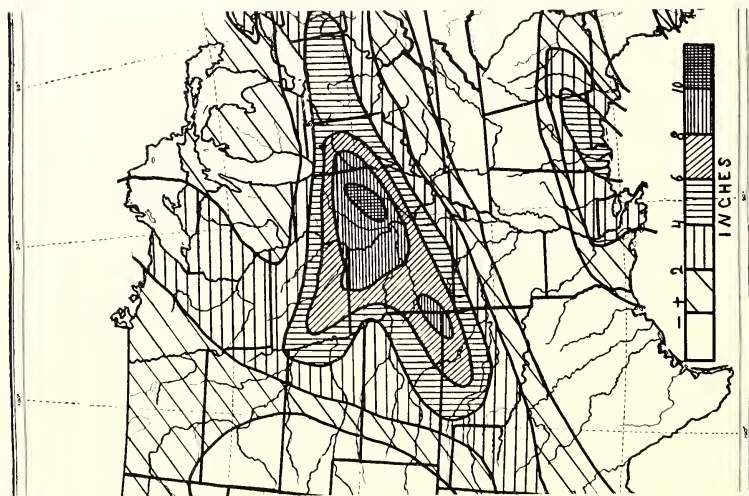


Fig. 1—Precipitation. Departures from normal. September, 1926. (Adapted from Monthly Weather Review for September, 1926.)

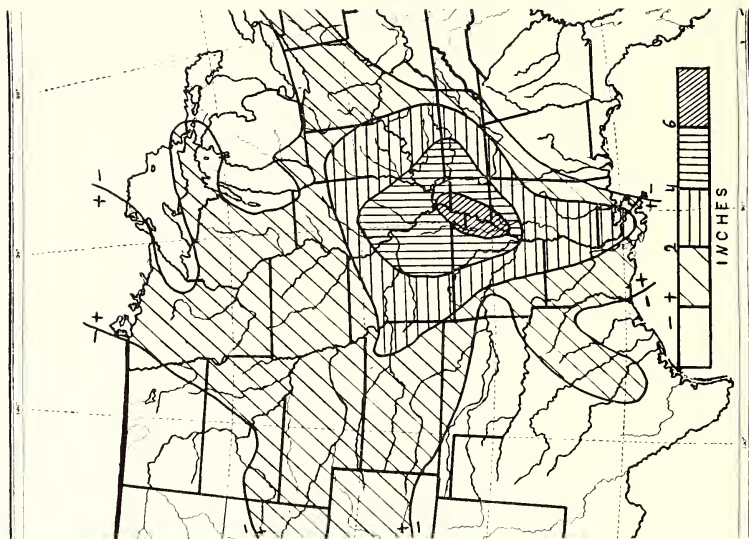


Fig. 2—Precipitation. Departures from the normal. March, 1927. (Adapted from Monthly Weather Review for March, 1927.)

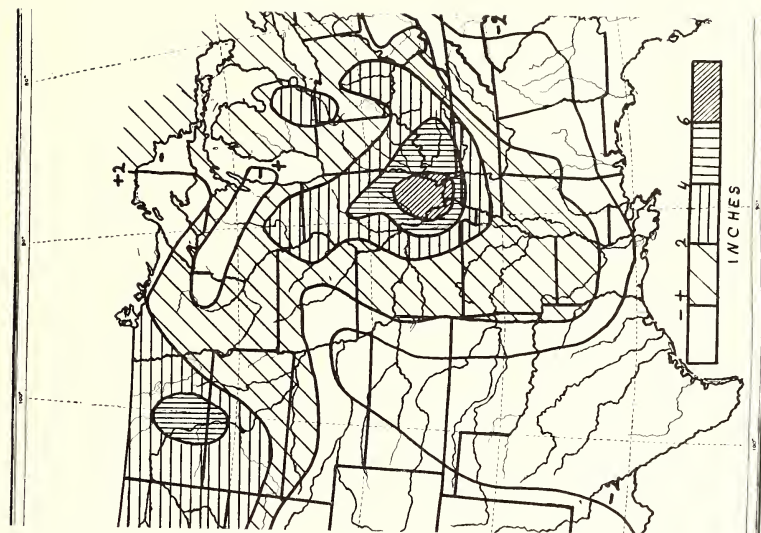


Fig. 4—Departures from the normal precipitation, May, 1927. (Adapted from Monthly Weather Review for May, 1927.)

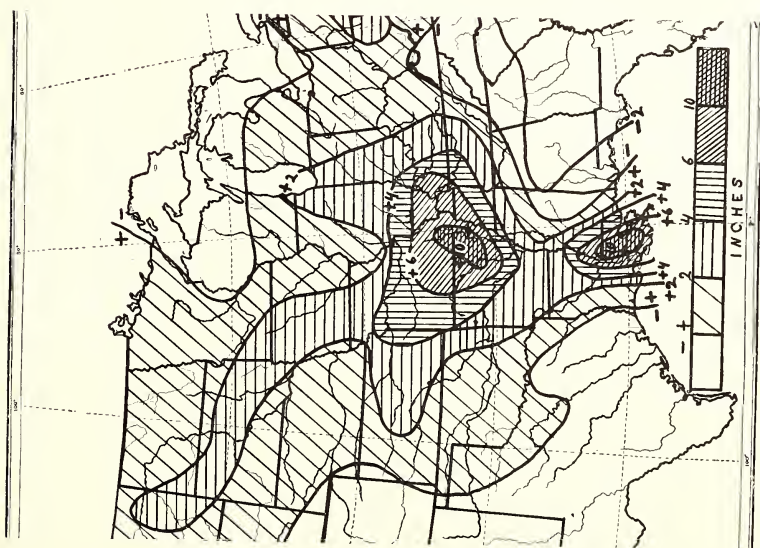


Fig. 3—Precipitation. Departures from normal, April, 1927. (Adapted from Monthly Weather Review for April, 1927.)

chiefly during the latter part of the month. In some of this area over 10 inches fell in less than a week. Excessive high stages in the Tennessee and Cumberland rivers with great loss of property was the result. With precipitation below normal during the first half of January in the Ohio, Cumberland, and Tennessee basins, the waters rapidly receded, and by the last of January they and the Arkansas were all in low water stages.

Heavy rains in the lower Ohio River Basin and an excess throughout its course in the latter half of January caused another rapid rise of the Ohio and its tributaries, reaching a crest of 55 feet at Louisville on Jan. 30. Excess precipitation in February was confined to the upper Tennessee and Ohio River basins, to the lower Mississippi, and to the Mississippi-Missouri basin of the Great Plains. The high waters of the previous months had by this time brought the lower Mississippi to flood stage, while the tributary streams returned to low water stages.

In March a large excess of rainfall occurred throughout nearly the whole of the Mississippi Basin, except in the upper Arkansas and upper Red River basins. The center of the greatest excess was in the immediate vicinity of the Mississippi River from Cairo to Memphis. (Fig. 2.) Western Tennessee, draining directly into the Mississippi and Tennessee rivers, reported unusual downpours on Mar. 8, 9, 12, 13, and 18 to 21. Half the stations reported over three inches of rainfall on March 12, the other half reporting over two inches. Floods in the Tennessee extended upstream to Florence, Ala., inundating 23,000 acres in the valley of the Tennessee River. In the lower Ohio, flood stages were reached throughout the course of the river below Louisville, and in its tributaries. Only in the Wabash and Green rivers, however, were the floods serious.⁹

The precipitation of April was very heavy in the middle and lower Mississippi valley and its adjoining territory. (Fig. 3.) The rainfall in this area between Apr. 1 and 20 probably exceeded all previous records, both in total amounts and in the length of period in which rains were of almost daily occurrence. The monthly amounts were from 10 to 15 inches over most of the area.¹⁰ In Kentucky, Tennessee, and Mississippi the heavy precipitation was confined to the western part of the states draining directly into the Mississippi River. In Arkansas, the average for the state was 12.93 inches, the highest of any month on record. Some stations reported as much as 23.8 inches, and 24 hour records of rainfall reached 11.40 inches.¹¹ Local excessive rains occurred in Louisiana. New Orleans reported over 14 inches on Apr. 15 and 16.¹²

The precipitation areas of May showed about the same general distribution of regions of excess as April, but with less extremes. A deficiency occurred in the lower Mississippi Basin and in the upper waters of the Arkansas and the Red rivers. (Fig. 4.)

The precipitation of June was slightly above normal for most of the Mississippi Basin south of the Ohio and Missouri rivers. It had the

⁹ Mo. Weather Rev. vol. 55, p. 143-144, Mar., 1927.

¹⁰ Mo. Weather Rev. vol. 55, p. 197, Apr., 1927.

¹¹ Climatic Data for Arkansas, Apr., 1927.

¹² Mo. Weather Review, vol. 55, p. 195, Apr., 1927.

effect of keeping high water in the lower Mississippi. In July, however, throughout nearly all of the Mississippi basin precipitation was below normal, except in the upper Arkansas and Kansas river areas. In the Arkansas River Valley just as the people who had been driven out of their homes for weeks had returned and had made a beginning of the work of rehabilitation, excessive precipitation brought another threat of disaster. This was the first month since July, 1926, that a marked excess of precipitation had not occurred throughout a large part of the Mississippi Basin, practically every instance of which was noted for unusually heavy downpours in short periods of time.

Let us now note the effects of these in a general way upon the Mississippi River stages. Bank full stage of the Mississippi River at St. Louis was reached Oct. 1, 1926, and continued to Oct. 17. This was the immediate effect of the unusual heavy precipitation throughout this area during September and early October. (Fig. 1.) Throughout the three succeeding months the belts of heavier precipitation lay to the southward of St. Louis, hence the Mississippi here declined until the last of January.

Cairo, Ill., was on the southward margin of the belt of heavy September and October rains, and though the river rose from the accretion of waters from the north, the river did not reach flood stage there until it received the flood waters of the Ohio, Tennessee, and Cumberland rivers in the early part of January.

At Columbus, Ky., and Memphis, Tenn., flood stage was recorded Jan. 3, and at Greenville, Miss., Jan. 11. From Cairo to the gulf, nearly all gage stations on the Mississippi showed flood or near flood stages by the middle of January. North of Cairo, after the rise of September and early October, flood stage was not approached again until late March. A deficiency of precipitation north of the mouth of the Arkansas River during February showed its effect in decreased readings of the stream gages in that section of the river. In the lower course, the Mississippi continued to rise.

It is to be remembered that March, April, and May are months of normally high water, due to the melting of accumulated snows of winter and the usually heavier rains of those months. In 1927, this normal high water condition was accentuated by the abnormal fall season precipitation and the unusually heavy rains of December and January. Then through March, April, and May there was concentrated in the main Mississippi Valley a more or less continued period of excessive rainfall. Flood conditions reached throughout nearly the whole of the region south of the Ohio a higher stage than ever before recorded. Levees broke in many places on both sides of the river, inundating some 20,000 square miles of fertile land, destroying millions of property, and taking a toll of many lives. It was not until the middle of July that the waters receded within the banks of the main channel, and the work of rehabilitation was begun.

Under such conditions as those enumerated above, it is doubtful if any system of dikes and reservoirs yet conceived could have wholly prevented the disaster. It is obvious that storage dams in the western

part of the basin that might aid irrigation would have had no part in the prevention of the floods of the Mississippi in 1927. The heavy rains did not occur in that portion of the area. How small a part storage dams might have played in the head waters of the Ohio River system is indicated by the fact that in March, floods occurred in the Ohio below Louisville, and in the Cumberland and Tennessee rivers below Nashville and Florence, respectively. These, like most of the very high waters of the Mississippi, were due to extreme downpours in the immediate vicinity of the valleys of the streams, and in the narrower portions of their basins. All the above seems to indicate that flood prevention is a problem of many angles, and one to challenge the best and most mature thought of the nation.

GEOGRAPHY OF INDIANA AGRICULTURE.

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The importance of agriculture in Indiana and its intimate relations to geographic conditions requires that it receive much attention in any thoroughgoing discussion of Indiana geography. Although the general features of the geography of Indiana's agriculture are well known, many significant phases have only recently come to light, as a result of a detailed study. Some interesting conclusions are given here.

Crop Values.—There is a great contrast among the counties in the total value of crops, Benton County with \$4,400,000 in 1924 having most and Brown County, of average size, only \$400,000, or less than one-tenth as much per square mile as Benton County.

The section of the state which has the most valuable crops per square mile extends diagonally across the state from Union and Randolph counties on the east to Benton and Newton counties on the northwest. This zone, which is about 70 miles wide, had crops with an average value of about \$35 per acre, or more than twice the average for the rest of the state. The county totals were \$3,000,000 or more throughout this zone, except in Marion and some of the small but rich counties.

To the northeast of this richest belt, most of the counties had a 1924 crop valued at about two-thirds as much as in the richer belt, or approximately \$22 per acre. The northern county producing most in proportion to area was Elkhart and that producing least was Starke. Starke County's crops had an average value of only \$10 per acre of crop land, or little more than half the state average of \$19. Starke County tied with Brown County in being the poorest in the state in this regard.

South of the rich zone, most of the counties have crops worth less than a third as much as in the richer belt. However, in the lower Wabash Valley there is a notable exception to this generalization, for Knox, Gibson and Posey counties have crops valued at from 4.2 to 3.3 millions and Daviess and Sullivan over 2.3 millions. All of the counties of the unglaciated south-central part of the state have crops having a per acre average value of little more than \$11, which is also true of the counties along the Ohio River east of the unglaciated area. This is the more notable because a large share of the cultivated land in these rougher counties is along the valley bottoms, where the soil is relatively rich.

Corn.—In proportion to area, Indiana stands third in corn production. Repeatedly it has had the honor of producing the finest corn exhibited at the International Stock Show.

Corn is by far the main crop. It is grown on almost every farm and the acreage devoted to corn constitutes nearly one-half of the tilled

land or nearly one-fourth of the total area. In recent years about 4,500,000 acres of corn have produced almost 200,000,000 bushels a year.

There is considerable variation among the counties in the acreage devoted to corn. The average farm in the south-central part of the state has only about ten acres in corn whereas the average farm in the north-central plain has about 32 acres. There is a similar contrast in yield. The south-central and southeastern counties produced an average of only about 500,000 bushels each in 1924; the northern and north-eastern quarter an average of about 600,000 to 700,000 bushels each; but the counties in the rich central belt which extends across the state from Benton and Newton counties southeast to Wayne and Union produced an average of about 2,000,000 bushels each. Rush County led the state with 3,040,000 bushels. The lower Wabash Valley ranked high in 1924 also, Posey, Gibson and Knox producing an average of 2,500,000 bushels.

The yield in 1924 was the smallest in many years, an average of 25.6 bushels per acre in contrast to a state average of 43.5 bushels in 1925. Seldom, however, does the state annual yield fluctuate more than 10 per cent from the average, which is about 37 bushels.

Corn is an important crop in Indiana because the climate, soil and topography are all favorable to its production. Indiana's warm, moist summers, the long average period between the last killing frost in the spring and first in the fall and the rarity of severe hail storms are all more favorable for corn than are the conditions in most states. The average yield in Indiana is higher than that in several other important corn states, including Illinois, Missouri, Nebraska, and Minnesota, and is about 40 per cent higher than the average for the United States.

Wheat.—Wheat is second in value among Indiana crops. It has occupied about one-sixth of the crop land until the last few years, when it has occupied one-seventh. It is grown in all parts of the state, in rotation with other crops. The average yield per acre fluctuates widely with the weather. Between 1909 and 1925 the state average ranged from eight bushels per acre in 1912 and 12 bushels in 1916, 1920, and in 1921, to 21 bushels in 1918, 18.5 in 1917 and 17 in 1924. There is a normal fluctuation of 25 per cent from the average yield. This is in sharp contrast to the much more uniform yield of corn, in which there is a normal variation of only 10 per cent from the average. This is because Indiana's climate is much better suited to corn than to wheat. But the very speculative character of wheat is one reason why it is grown so widely in Indiana. The possibility of a large yield encourages the farmer to try it again. Perhaps a crop such as that of 1918 will be received. The fact that wheat requires little work and that at times when the farmer is not especially busy also encourages wheat production.

The distribution of wheat over the state has varied notably. A series of maps for each census since 1839 shows this clearly. The south-western tip of the state has been important since 1879, when many other western counties grew much wheat, and there was heavy produc-

tion also in the most northern counties. None of the later censuses record much wheat in the western counties north of Knox County, and the production recorded from all the northern counties was small from about 1880 to 1920. The southeast-central counties were important producers in 1879, 1899, 1919 and 1924, but in the other census years were relatively unimportant.

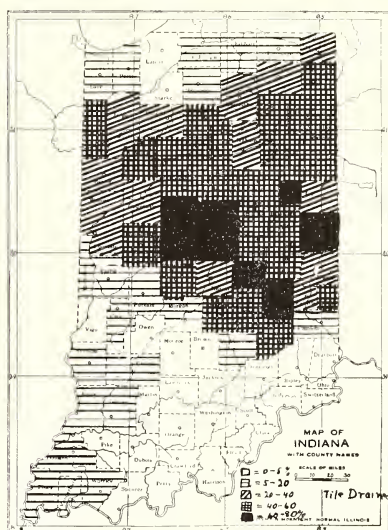
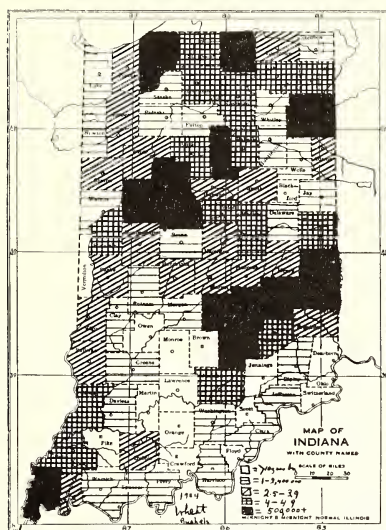


Fig. 1—Wheat yield 1924 (1925 Census) Fig. 2—Land tile-drained in 1924, percentage total area.
(Seven smallest counties doubled.)

The returns for the 1925 census are mapped in figure 1 and reveal a further change in wheat production. It shows a new area of intense production not shown on any map for the census years since 1839, although it is suggested on the map for 1879. The leading counties in Indiana in wheat production in 1924 were Clinton and Tippecanoe with 690,000 and 630,000 bushels, respectively. Several counties nearby also ranked high, producing approximately 500,000 bushels each, or over twice the average for the state. It will be interesting to see whether this region will continue to find wheat profitable or will soon cease to be prominent in wheat production. One of the new varieties of wheat is better suited to conditions in that part of the state than any of the older varieties were.

Oats.—Oats now rank fourth in value among the crops of the state, being surpassed by corn and hay in both acreage and value and by wheat in value but not in acreage. About 1,700,000 acres are devoted to oats, of which about 100,000 acres are not threshed. The threshed part yields about 60,000,000 bushels of grain. The yield per acre varied, for the state average, from 21 bushels (1922) to 42 bushels (1917, 1918). The average for the 17 years 1909-1925 was about 33 bushels per acre.

Oats are grown in all parts of the state, but they occupy several times as large a proportion of the ground in the northern half as in the southern. In the south-central counties the yield is especially small, only 1,000 bushels being raised in Brown County in 1924 and less than 100,000 bushels in most southern and southeastern counties. In contrast, several northwestern counties produced over 2,000,000 bushels each, Benton County leading with 3,300,000. A second center of heavy production is in the northeast-central part of the state, from Grant to Allen counties, with an average of about 1,400,000 bushels.

Lesser Crops.—Many other crops are locally important in Indiana. A few of special interest are rye, barley, tomatoes, sweet corn, sugar beets, tobacco, onions, white potatoes and melons. The distribution of each of these over the state, as shown by maps made of the data collected by the 1925 census, may be briefly given.

Rye is grown most extensively in the central northern counties, LaPorte to LaGrange south almost to the Wabash River. There several counties harvested more than 4,000 acres and Kosciusko sowed nearly 8,000 acres. Several southeastern counties harvested from 1,000 to 3,000 acres. The total acreage harvested in 1924 (133,000 acres) was only one-half that in 1919, but apparently rye culture is spreading.

Barley is likewise chiefly grown in the northern quarter of the state, the counties with greatest production lying, however, at the extreme northwest and northeast corners of the state, and Kosciusko County. The only other counties with more than 10,000 bushels harvested in 1924 are Wayne and Harrison. There is no obvious reason why Harrison County should grow several times as much barley as other southern counties. Harrison County differs, however, from its neighbors conspicuously in regard to various crops and farm animals.

Tomatoes. Indiana is now the leading state in the culture of tomatoes for canning, growing about one-tenth of all the tomatoes grown in the United States and approximately one-fifth of those canned in factories. In 1924 there were 42,000 acres grown, several counties having from 1,000 to 2,000 acres and five counties between 2,000 and 4,000, namely Madison, Tipton, Grant, Jackson and Daviess. The first three of these counties are together and are situated north and northeast of Indianapolis, and are bordered by four counties (Delaware, Henry, Hancock, and Marion), each producing from 1,000 to 2,000 acres. Jackson County is in south-central Indiana and two counties (Scott and Clark) between it and Louisville also grew over 1,000 acres of tomatoes. Daviess County is in southwestern Indiana, and has no neighbor which grows nearly as many tomatoes, although Gibson County, not far away, grew nearly 1,000 acres, especially for the catsup factory at Princeton. The only county in the northern third of the state growing more than about 100 acres is Kosciusko, which grew nearly 1,000 acres.

Sweet Corn. Indiana farmers grew about 31,000 acres of sweet corn for canning, or about one-twelfth of the nation's total, in 1924. Indiana was notably surpassed only by Illinois and Iowa. In Indiana,

a dozen central counties grow three-fourths of the state's sweet corn and an even larger percentage of the corn for canning. The leading counties with their acreage are Shelby (5,200), Miami (2,800), Madison (1,920), Bartholomew (1,620), Tipton (1,500), Marion and Wabash (each 1,250), and Boone, Hamilton and Johnson (each 500 to 900). The only other counties having over 500 acres are Vigo and Vermillion, along the western state line, each with slightly over 500. None of the southern counties have as much as 100 acres except Vanderburgh (200) and Floyd (120). None of the northernmost counties have more than about 200 acres except Lake County (300).

Sugar beets occupied 6,600 acres in 1924, three counties growing two-thirds of the crop, namely Allen (1,200), Adams (1,250) and Grant (1,000). Other important counties are Wells (830), Jay (600), Tipton (420) and Madison (250). All of these counties are near together in the northeast-central part of the state. No other county had as many as 25 acres.

Tobacco. Indiana farmers devoted 20,700 acres to tobacco in 1924, and produced about 19,000,000 pounds, valued at \$3,113,000, chiefly in counties situated along the Ohio River. The leading counties are Switzerland (3,450), Jefferson (3,100), Spencer (2,625), and Warrick (2,160). Other counties with more than 1,000 acres in tobacco were Clark (1,400), Harrison (1,325) and Dearborn (1,245), along the Ohio River also, and in addition, Franklin County (1,290), adjacent to the area of extensive tobacco culture in Ohio, and just north of Dearborn County. No county in the northern two-thirds of the state raised as much as 100 acres of tobacco except Randolph, on the Ohio boundary. Tobacco is reported from only three counties of the northern half of the state. Very little is also given in the southwestern counties north or west of Warrick County, which is on the Ohio River just east of Evansville. Indiana grows far less tobacco than is grown in counties in Kentucky and Ohio just across the state line, where climate and soil are similar to areas in Indiana. This is not unfortunate, however, as tobacco exhausts the fertility of the soil very rapidly, and, as most tobacco fields in this region are on rather steep hillsides, soil erosion also is rapid. Such hillsides had far better grow trees.

Onions (dry) occupied 8,345 acres in 1924, chiefly in the northern counties. No central or southern county had as much as 100 acres. The leading counties in onion growing are in the northeastern corner of the state and are as follows: Whitley (1,440 acres), Noble (1,422), Kosciusko (927).

White potatoes were grown on about 44,000 acres in 1924, the average yield being nearly 100 bushels per acre. More than 500 acres per county are grown in almost all of the counties bordering the Ohio River, Harrison with 1,500 acres leading in this group. The potatoes grown in these southern counties are chiefly early varieties. The northernmost counties of the state grow many late potatoes, St. Joseph County leading with 2,600 acres. Others with over 1,000 acres are LaPorte, Elkhart, LaGrange, DeKalb, Allen, Kosciusko and Marshall.

Melons are chiefly grown in the lower Wabash Valley. Of the state's 13,000 acres of melons, about a half are grown in three counties. Gibson County raised about 2,000 acres of muskmelons and canteloupes and 1,200 acres of watermelons. Knox County raised 800 acres of watermelons and 1,300 acres of other melons. Jackson county, in south-central Indiana, devoted about 1,000 acres to melons, half of it to watermelons.

Poultry.—Indiana is a leading poultry state, raising a total of over 25,000,000 chickens in 1924, valued at about \$20,000,000, and laying 87,000,000 dozen eggs valued at \$25,000,000. Hence poultry yielded over \$45,000,000 or nearly \$15 for each person in the state.

The distribution of poultry over the state is by no means uniform. A map, based on the 1926 report from the Department of Agricultural Statistics, reveals that the counties having most poultry are in the northeastern quarter of the state, except two, Ripley and Harrison. The counties with fewest poultry are situated south and southeast of Indianapolis, but the western tier of counties also have relatively few, except Sullivan and Knox, which have about 150,000 each.

Comparisons with other geographic maps of Indiana reveal some interesting correspondences and differences. The northeastern counties which have most poultry are, except Hamilton County, situated in the region where the average period between the last killing frost in spring and the first in the fall is less than 160 days. Apparently in the neighboring counties to the west and south, where the growing season is longer than 160 days, corn production succeeds enough better so that there is less incentive to raise chickens than in these cooler more northeastern counties. The relative sparsity of poultry in the western tier of counties corresponds with the distribution of silos, cows, tenancy and the percentage of corn crop sold for cash. None of the counties having most valuable farm land, on the average, or those which produce the most valuable crops per acre are black in the poultry map (have more than 14,000 dozen poultry), with the exception of Hamilton County. No one of the poorest counties in the state or the counties which lost population between 1910 and 1920 or between 1890 and 1920 have much poultry. Apparently the extensive raising of poultry is associated with moderate prosperity, though not with opulence. No county with the fewest sheep have also few chickens, except Marion County. Several of the counties with most sheep also have most poultry. All of the counties having numerous sheep also have numerous poultry except Fountain and Parke. Of special interest is the fact that all of the counties having most poultry (more than 150,000) have had, for the average of eight years, relatively few deaths of infants under one year, except Ripley County. This may be a mere coincidence, but experts on diet have recently been stressing the importance for children of the vitamins found in eggs.

Milk Cows.—The distribution of milk cows over the state has been mapped and reveals some rather striking contrasts among the counties. The counties along the western margin of the state from Lake to Knox

have relatively few milk cows, from 3,100 to 5,000, and the counties along the Ohio have relatively few also, except those counties which are nearest to Louisville and Cincinnati. Also the counties of the rougher, unglaciated part of the state have less than 6,000, except the four counties nearest Louisville. On the other hand, the counties surrounding Marion County have 6,000 or more, except Morgan County. Hamilton with about 10,000 is surpassed only by Elkhart County, with 10,600. Kosciusko, Marshall and LaPorte counties have nearly 10,000 apiece and other northern counties rank high, except Starke.

In proportion to population, 22 of the 92 counties have a cow for not more than three persons, whereas the six counties having the state's largest cities have ten or more persons per cow. The counties with relatively many cows in proportion to population are in the northern part of the state, north of the North Central Plain upon which corn dominates. Three counties bordering Marion also have many cows in proportion to population, namely Hendricks, Hamilton and Hancock. Washington and Harrison counties apparently contribute to Louisville's milk supply and Jennings, Ripley, Franklin, Switzerland, and Ohio, to Cincinnati's supply. Aside from the counties with large cities, the counties having fewest cows in proportion to population are Vermillion, Floyd, Madison, Grant, and Delaware.

Comparisons with the map showing the distribution of silos reveals rather close correspondence with the number of cows, as might be expected since silage is chiefly fed to milk cows. There are, however, relatively more silos in proportion to cows in the northern part of the state and fewer in the southern, where there is less snowfall and a longer grazing season.

Beef Cattle.—Indiana farmers had 102,000 steers over a year old in 1925, according to the agricultural census of that year. Their distribution over the state is very irregular and shows some interesting relationship. Steers are relatively few in the southern half of the state, there being on the average less than 1,000 in each county; indeed, 17 counties have less than 500 each. Only two counties have more than 1,600, but these two, Decatur (4,130) and Hendricks (3,100) are among the state's leaders. In the northern half of the state, only one county (Starke) has less than about 400 steers and ten counties have over 2,000, while five have over 3,000. Jasper County led the state in 1925 with 4,700 steers over a year old on farms. The section of the state with most steers is that north of the Wabash River and Benton County; in other words, north of the Corn Belt proper. In that section, only Starke and St. Joseph counties have less than 500 and the average is fully 2,000 per county.

It is interesting to note that none of the counties leading in the number of milk cows also leads in beef cattle. Likewise, and even more surprising, is the fact that none of the counties having over 2,000 steers are leaders in the number of swine, and conversely, no county having relatively many swine (over 50,000) has relatively many steers (over 2,500).

Sheep.—Indiana has about 600,000 sheep, but they are distributed over the state very unequally. The northeastern six counties have most, Steuben leading with 20,000. Jay and Boone counties, however, also have about 11,000 each. The counties of the southern third of the state have relatively few sheep, almost all of them less than 3,000 apiece, and a dozen of them have less than 1,000 apiece. It would appear that these rougher southern counties might advantageously pasture many more sheep. But there are so many dogs in that part of the state that sheep raising is precarious, in spite of the fact that sheep killed by dogs are eventually paid for out of the dog-tax fund.

The relatively extensive sheep raising in the northeastern corner of the state is partly in response to the fact that because of the higher elevation and the northern location, that section is the coolest in the state, on the average, and is too cool for the extensive production of corn. All of the counties in the part of the state having a growing season of less than 160 days, on the average, have more than 5,000 sheep each. The only other counties with that many sheep are just west and northwest of Indianapolis and just east of Indianapolis.

Mules.—There were 101,000 mules in Indiana at the taking of the 1925 federal agricultural census, about 1,000 more than at the 1920 census, whereas that five-year period showed a decrease of 161,000 horses. Hence the mule is increasingly worthy of respect. More than three-fourths of the mules are found in the southwestern half of the state, no county northeast of a line drawn from Lake County to Dearborn County having as many as 1,000 mules, and most of them having only about 500. The counties southwest of that line have an average of about 2,000 mules each, although some of them have slightly less than 1,000. The counties with most mules are in the extreme southwest corner, Knox to Posey and Warrick, with from about 3,000 to 4,200 each. Jackson County also has approximately 4,000 mules. None of the counties in the northern two-thirds of the state have more than about 1,000 mules, whereas the counties in the southern third of the state average about 2,000 each. The fact that most democratic counties are situated in the southern third of the state might be thought to explain the distribution of mules. However, three of the six counties having most mules are predominately republican in politics! The numerous mules on the lower Wabash Valley is apparently related in part to the high average summer temperature there.

Swine.—There were almost exactly 3,000,000 swine on Indiana farms on January 1, 1925, nearly one per person in the state, and nearly four for each person on the farms. Their distribution over the state was decidedly irregular. However, Rush County with 82,500, had nearly 30 times as many as Brown County, which is almost as large. Other leading hog producing counties are Henry, Randolph, Montgomery, Hendricks, each with from 64,000 to 67,000, and in proportion to their size, also Fayette and Union. The leading hog raising counties make a triangular area with its apex as Montgomery County and the base along the Ohio border from Allen to Union counties. In that area the

counties have approximately 60,000 hogs, except Marion (24), Jay (30), and Adams (37). No Indiana counties not in this triangle or bordering it had as many as 40,000 hogs except Knox and Gibson, in the lower Wabash Valley, which had 42,000 and 45,000. The other counties in the southern third of the state had an average of about 20,000 hogs, but ten of them had fewer than 10,000, and five of them less than 6,000 (Ohio, Switzerland, Floyd, Crawford, and Brown). The northern counties with fewest hogs are Starke (8.6), Lake (13.2), and Vermillion (14.9).

Farm Tenancy.—According to the special agricultural census, returns for which have recently been issued by the U. S. Bureau of Census, 29.2 per cent of Indiana's farmers were tenants in 1925. In other words, of the approximately 200,000 farms in the state, about 60,000 were in the hands of tenants. The percentage of farms worked by tenants varies widely among the 92 counties, ranging from 58 per cent in Benton County to 10 per cent in Perry County.

When the percentage of tenancy in Indiana is mapped, it is seen that the northwest-central part of the state has the most tenancy and the south-central part the least. The counties having the largest percentage of rented farms are Benton, Jasper, Newton, White and Warren, with from 58 per cent to 46 per cent. These contiguous counties are in the area of most intense corn production, adjacent to the part of Illinois which produces most corn. Counties where from 40 to 45 per cent of all the farms are rented are Tippecanoe, Montgomery, Clinton, Pulaski, and Tipton, all near the counties having most tenancy. Rush County, southeast of Indianapolis, also has much tenancy (42 per cent).

The other counties of the North Central Plain have from 30 to 39 per cent of their farms rented, as is also true of three counties in the lower Wabash Valley, namely, Posey, Gibson and Knox.

In the more rugged and less fertile parts of the state, most farms will not readily produce enough to support two families, a tenant and the owner. Indeed, many of the farms will not adequately support one family. Hence tenancy is far less general. The counties which were not smoothed off by the ancient glaciers have only about 1/10 to 1/8 of their farms rented, and many of which yield the owners very little rent. The counties where from 10 to 13 per cent of the farms are rented are Perry, Lawrence, Dubois, Orange, Floyd, Brown, Monroe and Washington. These are close together. To the east of this area, Ripley County, much of which has relatively unproductive soils, has only 14 per cent of tenancy, in contrast with neighbors which have from 21 to 29 per cent.

Farm tenancy in Indiana is less now than it was in 1920 or in 1910. A recent special federal report on tenancy in the corn belt states concludes that there is no occasion for great alarm concerning farm tenancy even in that area where, as in several Indiana counties, about half the land is in the hands of tenants. Most of the tenant farmers in these fine counties are sons or sons-in-laws of the owners. Few owners have more than two farms and most owners have more than two children, among whom the land will be divided.

Most farm tenants in Indiana are share tenants, only one-thirteenth of the crop-land being rented for cash. A map showing the distribution of cash rentals resembles in a general way the map of all tenancy but reveals some interesting contrasts. Cash renting is most prevalent in the North Central Plain, but not in the northwestern part, where total tenancy is most conspicuous. The counties having over 4,000 acres rented for cash are nearly all situated to the northeast of Indianapolis, between it and Ft. Wayne. Exceptions are Lake County, and adjacent Porter and Newton, where truck farmers raise many onions, cabbages, etc., for the markets of Chicago.

Farm Improvements.—Travelers often judge the progressiveness of people and the value of land by the character of the farm buildings and other improvements. A large share of Indiana's farms are well improved. On the average the improvements have an assessed value of about \$10,000 a square mile. In other words, as there are in Indiana about six farms to the square mile, the average improvements on each farm have an assessed value approaching \$2,000. However, there are marked contrasts in the value of improvements in different parts of the state, as is seen when a map is made showing the average value a square mile (obtained by dividing the total assessed value of improvements on farms in each county as given in the last report of the State Auditor, by the area of each county). Almost all the counties having farm improvements assessed at \$9,000 or more a square mile are situated in the central part of the state, forming a triangle with its western point as Tippecanoe County and its base along the eastern margin of the state from the northeastern corner south to Union County. In that third of the state only one county, Jay, has less than an average of \$9,400 worth a square mile of assessed improvement on farms. The best improved counties according to these data are Marion, Howard and Delaware. Only four counties not in this triangular area had assessed improvements on farms averaging over \$9,000. They were Elkhart, St. Joseph, Vigo, and Vanderburgh. Doubtless a considerable share of the improvements not on city lots in the last two counties were coal mining tipples and hoists, as these counties mine much coal.

The south-central counties have farm improvements assessed at an average of only about \$4,000 per square mile. The poorest counties in this regard are Brown (1.5), Crawford (1.9), Martin (2.1), Perry (2.3), Washington (3.3), Dubois (3.5), and Owen (3.6). The low rank of these counties in value of improvements is not unexpected, as rough land is common and in most of it the people are relatively poor. It is surprising, however, to discover that four counties in the northwestern part of the state have farm improvements only a little more valuable per average square mile than those in the state's poorest counties. These four counties are Newton (3.9), Jasper and Pulaski (each 4.6), and Warren (4.9). Benton and White counties also are far below the average for the state. Tenants are common in these counties and the average farm is large, and obviously not very well improved.

None of the counties in the southern third of the state have farm improvements assessed for more than about \$5,000 per average square

mile except Vanderburgh (19.7), Knox (8.6), Gibson (7.6), Floyd (8.1), and Decatur (8.5).

Farm Machinery.—Indiana farms had machinery and implements valued at \$80,000,000, according to the special agricultural census of 1925. Conspicuous regional contrast is present, all of the counties which have more than about \$1,000,000 worth of farm machinery being situated in the northeastern half of the state. None of the counties southwest of a line extending from Benton County southeast to the southeastern corner of the state have more than about \$1,000,000 worth and only Knox, Gibson and Jackson closely approach that figure. On the average this southwestern nearly one-half of the state reported farm machinery and implements worth only \$500,000 per county. The poorest counties were Brown (\$200,000), Crawford, Monroe, Martin, Scott and Owen (each about \$300,000), and Lawrence, Orange, Perry and Jennings (each about \$400,000).

In the northeastern half of the state only a few counties have less than \$1,000,000 worth of reported farm implements and machinery, the poorest being Starke (.7), Steuben, Howard, and Tipton (.8 each) and tiny Blackford, Union and Fayette (.4 to .6). The richest are Allen, Kosciusko, Carroll and Shelby with from 1.5 to \$2,000,000.

Tractors on Farms.—Indiana farmers had about 2,400 tractors in 1925, according to the special agricultural census. Thus, if they were distributed equally, each county would contain about 250, and one farmer in every eight would have one. But, of course, the distribution is not uniform. Tractors are relatively few in the southern third of the state, the third which is the more rugged and less prosperous. Counties with especially few are Ohio (20), Brown (26), Crawford (40), Owen (48), Monroe (69), Switzerland (75), Pike (76), Perry (90), and Martin (91). None of the southern counties have more than about 200 tractors except Knox, Gibson and Posey, in the lower Wabash, with about 300 apiece.

On the other hand, 15 counties in the east-central part of the state (Tippecanoe to Allen and Rush) have more than 400 tractors each. Allen has 795, Wells 507, and Hamilton 505. Few counties of the northern two-thirds of the state have fewer than about 200 tractors except tiny Blackford (70) and Steuben (130); few, in fact, have less than 300 tractors.

The 1920 Census did not enumerate farm tractors, but the Co-operative Bureau of Agricultural Statistics reported 15,000 in 1920. The increase of 9,000 by 1925 represents more than a 60 per cent increase, and it appears that the tractor has won a place for itself on the better equipped farms in central and northern Indiana.

Silos on Farms.—There were, according to the special federal agricultural census, about 17,000 silos in Indiana in 1925. The northernmost counties all have many silos, from 210 in DeKalb County to 610 in Lake and 650 in Porter. No other group of several counties in the state has as many silos as these, but nowhere else in the state are the winters quite so cold or so long or is there so much snow. The

increase in number of silos from the northeast corner towards the northwest is apparently in response to the large market for fresh milk in Chicago.

The second group of counties with more than 300 silos each are counties sending much milk to Indianapolis. Madison, Hamilton, Delaware, Hendricks, and Marion each have 300 to 400 silos.

The only other counties in the state with 300 or more silos are Dearborn (370) and Ripley (350) both of which send much milk to Cincinnati; and Clark (310), across the river from Louisville.

Nearly all of the counties of the western part of the state south of Lake County have relatively few silos. Benton County, which usually leads the state in total corn production, has only 100 silos. Much of the corn of this area is sold for use in Chicago. Vigo and other western counties formerly sold much of their corn to Terre Haute distilleries. A large share of the corn raised in the lower Wabash Valley is grown on the low bottoms which are subject to flooding. The stalks there are also very rank, having relatively less value for silage than in most of the state. Thus the relative sparsity of silos in western Indiana is apparently due to a combination of unfavorable conditions. Nevertheless, Knox and Daviess counties have from 140 to 190 silos, or about twice as many as their neighbors.

Tiled Land.—Much of Indiana was wet land a century ago, and there were many marshes. Wild ducks nested in large numbers in the state, and mosquitoes were prevalent, and malarial fever or ague common.

Many of the pioneers of a century ago, after traveling about the state in search of land, settled on lands that today have only a small fraction of the value now possessed by lands long unoccupied. The pioneers could not anticipate future inventions and development and did not realize the abiding worth of the nearly level acres of deep soil. To many of the earlier pioneers, the rolling land of southern Indiana seemed the best in the state. It was naturally well-drained, possessed fine woods, abundant game, numerous springs, and attractive forage. Furthermore, when first cleared, the soil was fertile. Travel from place to place by the common modes of those days, which was afoot, on horseback, or with oxen, was less hindered by the ruggedness of much of southern Indiana than it was in the more level northern regions where swamps and relatively deep, unbridged streams interfered greatly.

The construction of roads and railroads, and artificial drainage has of course changed the situation greatly. There are in Indiana hundreds of miles of open ditches and tens of thousands of miles of drain tile converting many formerly worthless swamps into choice farm lands. A map showing the distribution of tiled land has recently been made. Figure 2 reveals a notable concentration of tile drainage in the north-central plain, where most of the counties have about half of their areas tiled. Boone, Hendricks, Hamilton, Hancock, Rush, Randolph and Blackford have over 60 per cent, and Tipton has over 90 per cent. In contrast, none of the south-central or far southeastern counties have as much as five per cent of their land tiled, nor do Vigo, LaPorte and Starke counties. None of the southwestern or the far northern counties

have more than 20 per cent tiled, except Steuben (25 per cent). But some of those have extensive open ditch drainage.

Farm Woodland.—The 1925 special agricultural census classified Indiana farm lands more thoroughly than previous federal censuses have done. Of the 20,000,000 acres in farms, 12,000,000 was classed as cropland, and 5,700,000 as pasture-land. About half of the pasture is plowable and half of the remainder is woodland pasture. In addition to 1,900,000 of woodland pasture there were in 1925 about 840,000 acres of woodland not used for pasture. In other words, slightly more than one-eighth of the state is classed as woodland, two-thirds of which is regularly pastured, and practically all of it has been cut-over repeatedly, so that little large valuable timber remains. In 1925 it yielded about 1,000,000 cords of firewood, according to these census returns. A century ago at least four-fifths of the state was forested, most of it with timber of exceptional size and quality.

The distribution over the state of woodland reveals interesting irregularity. Of the total woodland Benton County has only 4,000 acres, practically all of which is pastured. Other counties having less than 20,000 acres are Warren, Lake, Porter, Adams, Clinton, and Howard, Tipton, Johnson, as well as the five extreme southwestern counties (and the six smallest counties in the state). At the other extreme, there are 12 counties with over 50,000 acres of woodland, all located in the south-central part of the state or the southwest-central part. Perry County, on the Ohio River, has most, 78,500 acres, but Washington, Parke and Putnam each have over 73,000 acres. These counties are mostly in the unglaciated, more rugged part of the state, or along the rocky belt just east of the Wabash Lowland. The only counties in the northern half of the state having more than 30,000 acres of farm woodland form a belt from Jasper east to Allen County, along the more rugged south margin of the area covered by the last Great Ice Sheet which extended into Indiana.

Woodland not used for pasture in 1925 is conspicuously sparse in all the central counties, where few have as much as 2,000 acres. On the other hand, it is relatively very extensive in the south-central counties from Brown to Harrison and along the Ohio River from Clark to Perry County. These counties have from 20,000 to 52,000 (Perry County) acres of unpastured woodland belonging to farms as well as many areas not in any farm. Neighboring counties have from 12,000 to 20,000 acres. The limestone belt (Monroe, Lawrence, Orange) has conspicuously less unpastured woodland than the rougher adjacent counties to the east and west.

The northern counties, those north of the North Central Plain (Tipton Till Plain), were covered by the last advance of the continental glacier and have many undrained depressions, and small hills. These counties have an average of about 7,000 acres of unpastured woodland, Starke County having most (11,400).

Farm Size.—The average farm in Indiana contains 102 acres, according to the 1925 agricultural census. The variation among the 92

counties of the state is notable. The farms of Newton and Benton counties are about three times as large, on the average, as those of Floyd and Vanderburgh counties (207 acres vs. 68). When the average acreage of farms is mapped, interesting regional contrasts become conspicuous. The counties having the largest average farms are all between the Kankakee and the Wabash rivers in northwest-central Indiana. The six western counties of that area have averages above 155 acres per farm and the average for the six counties is 177 acres. Newton and Benton average 208 and 207 acres. In no part of the state except the northwest quarter do the farms average as much as 120 acres except in the southeast-central part. There, in Rush, Decatur, Fayette, and Union counties, the farms average about 130 acres.

The farms of most of central Indiana are notably smaller than those in the flat, black-soil area of the Kankakee region. The average farm of east-central Indiana has only about 90 acres, and many farms have only one eighty. Many of these smaller farms afford excellent examples to the farmers of other regions. The United States Department of Agriculture issued a Farmers' Bulletin recently on "Successful Eighty Acre Farms in the Corn Belt of Indiana." This bulletin, which was based on a study of individual farms, showed how even in the trying years of 1921-1924 farm owners who showed the proper resourcefulness, industry and skill were able to make a fair return on 8-acre farms in the favored region. The implication was that by the use of similar methods, farmers in other regions could make a fair return on somewhat larger farms.

One might expect that the richer land of central Indiana could be divided into smaller farms than the poorer land of southern Indiana, where a larger acreage is required to adequately support a family. However, the average farm of the southern third of the state is distinctly smaller than the state's average, and a smaller percentage of each farm is in crops. As the average yield per acre is less also, this means that in general the farmers of southern Indiana have to live more economically than the farm owners of the rest of the state.

The average size of Indiana's farms is increasing. In 1925 it was two acres more than in 1920 and three acres more than in 1910, when the average farm had 99 acres. A map showing the change between 1910 and 1925 in the average acreage reveals that in the northern quarter of the state farms are being subdivided slightly more than they are being combined, and hence the average acreage in 1925 was a little less than in 1910. In central Indiana the average farm is notably larger now than in 1910, for most counties about 10 acres larger. In the southern third of the state, there has been little change in average size of farms. In five counties the average farm is now about 80 acres larger than in 1910, while in five counties it is about that much smaller. In the remaining counties the change has been less; in eight counties less than an acre change.

Farm Land Values.—At the 1920 census the average value of farm land, not including the value of the buildings, was for Indiana \$104.60 per acre. At the 1925 census, the corresponding figure was \$63.71,

showing a drop of about \$40.00 for the average acre. However, the present value is higher than that at the 1910 census and if the prices of the things which farmers must buy had dropped since 1920 as much as the value of his land has dropped, the farmers, on the average, would not have much basis for complaint.

A map showing the distribution of per acre farm land values (excluding buildings) reveals some interesting conditions.

In none of the counties of the southern third of the state was the farm land alone reported to the census takers as being worth more than an average of about \$50 per acre, except in Knox (\$75), Vanderburgh (\$66) and Bartholomew (\$72) counties. The only counties of the northern two-thirds of the state with land worth less than about \$60 an acre on the average were Steuben (\$42), Noble (\$52), Whitley (\$53), and four counties adjoining the poor south-central section, namely Morgan (\$51), Putnam (\$44), Clay (\$44), and Owen (\$27). Fifteen southern counties had an average value of less than \$30 per acre. The poorest were Brown, Crawford, and Perry (\$15 each), Martin (\$18), Harrison (\$20), Orange (\$21), Jennings (\$22), Washington (\$24), Jefferson (\$26), Ripley and Owen (\$27), Scott and Dubois (\$28).

Except Marion County (\$184), with values inflated by the marvelous growth of Indianapolis, the counties with the most valuable farm land alone are Benton (\$142), Tipton (\$113), Newton (\$104), Tippecanoe (\$103), Clinton (\$101), and Howard (\$100).

In respect to glaciation, Indiana may be divided into four regions. First, the south-central area, which was not glaciated, where the farm land had in 1925 an average value of about \$20 an acre, and where there is much waste land, not included in the farm area. Second, the areas to the east and west of the unglaciated area, which were covered by an early ice sheet only (the Illinoian). There the soil has had time to lose a considerable part of its fertility, and to become sour, on level areas. The average value of land in this area of ancient glaciation is about twice as great as in the unglaciated area, although the counties in the southeastern part of the state, along the Ohio River, are rough or possess much relatively infertile clay from shale, and have an average value of only about \$30 per acre. The greater part of Indiana, the North Central Plain, was covered by the Early Wisconsin Glacier and not enough time has elapsed since for the fertility to be leached from the soil or for it to sour. In this large region, the average value of the land alone is about \$90 per acre, or four and a half times as much as in the unglaciated section, and three times as much as in the section covered only by the Illinoian ice sheet. Fourth, the northern fourth of the state was covered by the Late Wisconsin Ice Sheet, the last to advance into the state, and many of the marshes and lakes it created are still present, and numerous small areas are hilly with small hills and others are sandy. Hence the average value of the land is less, about \$60 if the effect of the cities of Lake and St. Joseph counties be discounted. But still it is three times as valuable as the unglaciated area.

Cooperative Selling.—Farmers are highly individualistic and hence cooperative activity is relatively slight. However, the recent “hard

times" have made many farmers realize that they must cooperate if they are to receive a fair price for their products, and if they are to have anything to say as to what is a fair price for the commodities which they purchase. Therefore there has been a notable growth in cooperative marketing. As yet in Indiana this is largely confined to cooperative selling. In 1924, according to the 1925 Agricultural Census, Indiana farmers sold cooperatively a total of \$17,200,000 worth of farm products. But they purchased a total of only \$1,800,000 worth of products, or only about one-tenth as much.

The southern third of the state displays relatively very little cooperation; in general, the poorest counties standing lowest. The farmers of Brown and Crawford counties each sold only about \$200,000 worth cooperatively. The richer counties of the lower Wabash Valley are indeed not far below the state's average, but only Knox County sold more than about \$270,000 worth. Knox sold \$444,000. To be sure, most of these southern counties produce much less than most northern counties, and themselves use a larger portion of what they produce, but even after due allowance has been made for these conditions, the southern counties are seen to fall behind in cooperative selling, as they likewise do in education and in many other respects.

In the northern two-thirds of the state, there is notably more cooperative selling in the eastern half than in the western. The counties where a large percentage of the farms are rented display relatively poor cooperation. Tenants apparently are less interested in cooperation than are farmers who own their land. The leading counties in cooperative selling are LaGrange, Marshall, Kosciusko, Whitley, Wells, Randolph, Wayne, Fayette, and Rush, each of which sold more than \$400,000 worth. Kosciusko County leads with \$591,000, although in proportion to its size Fayette did as well. In counties bordering these nine are several counties selling from \$300,000 to \$400,000 worth, in which class are also five counties bordering Boone County in west-central Indiana.

FURTHER OBSERVATIONS OF THE EROSION OF CLIFTY AND BUTLER RAVINES, JEFFER- SON COUNTY, INDIANA.

J. ARCHER CULBERTSON, Shortridge High School, Indianapolis.

In the Proceedings of the Indiana Academy for 1897 there is given an account of preliminary work, looking forward to the approximate determination of the time required for the erosion of Clifty and Butler valleys. This preliminary work was done by Dr. Glenn Culbertson of Hanover College. It consisted in making accurate measurements of the length of the valleys mentioned, in drilling holes and driving steel rods into the rocks both above and in the amphitheater-like space beneath the falls, and in making accurate measurements from these rods so that the rate of recession of the falls could be determined.



Fig. 1—Clifty Falls. Iron rod at (a). At present most of the mist from the falls strikes the cliff at point marked (b).

“Proc. Ind. Acad. Sci., vol. 37, 1927 (1928).”

In 1911 (Proc. Ind. Acad. Sci.) it was noted that measurements from the rods driven in the bed of the stream above the falls produced no results of immediate value. But that the results from measurements of the rod driven in the softer strata below the falls were quite satisfactory, especially in the case of Clifty Falls.

Observations showed that during the 14 years between 1897 and 1911 the undermining at Clifty Falls amounted to four and one-fourth inches. The sapping, as it is sometimes called, is due principally to the weathering caused by the mists carried by the waterfall winds against the rocks, followed by frost action.

At the present time the weathering has amounted to seven and one-eighth inches, two and seven-eighths inches of which has taken place since 1911, 16 years ago. The rate of retreat for the first 14 years was approximately two-sevenths of an inch per year and for the last 16 years the figure is very nearly three-sixteenths of an inch, the average falling near one-fourth inch per year for the 30 years. The period required for the retreat of the falls from the edge of the deep valley of the Ohio, a distance of 11,000 feet, if the 30-year average has held throughout its history, should be 528,000 years. If the rate for the first 14 years were more accurate the period would be 462,000 years. It is probable that the latter figure is more nearly correct because in recent years erosion at the base of the falls has caused the waterfall winds to carry more mist against the rock some 30 feet north of the iron rod, which is directly behind the falling water. When the iron rod was placed the greatest amount of mist was directed against the cliff at that position. (Fig. 1.)

Because of the many variable factors in the erosion of this valley it is difficult to say just how accurate this figure may be. The rock over which the water flows is essentially of the same character as that over which the water flowed during the whole past history of the valley. Hence so far as that element is concerned, the erosion should have been uniform throughout the period of growth of the valley.

Whether or not the amount of water flowing over the falls at present is as great as in the past is a problem rather difficult of solution. The falls are in the main valley, yet as they have retreated through the two and one-twelfth miles, several tributaries have been left to work back their heads and their water no longer helped to erode the main falls. As far as this element is concerned, it may be that there is a smaller volume of water flowing over the falls than in the past, and hence a somewhat slower retreat.

To offset this factor, the valley above the falls has certainly been growing longer and developing tributaries in the flat Illinoian Glacial plain, and hence has been adding to its drainage area and volume of water during this period. The Wabash-Ohio divide would gradually shift westward. Because of this factor the falls may be retreating more rapidly than during the earlier period of its growth. The area drained by the tributaries above the falls is practically the same as the area drained by the tributaries which empty into the main stream below the falls, so possibly the present amount of water is not greatly different from the average of the whole period of retreat. (Fig. 2.)

Assuming that the amount of rainfall has been almost uniform it is probable that the rate of sapping beneath the falls and hence the retreat of the falls up the valley, is approximately that which has held throughout the history of its growth. According to the average estimate of the time lapsing since the Illinoian glacial advance it would seem that Clifty Valley came into existence near that time but probably practically all of the erosion has taken place since.

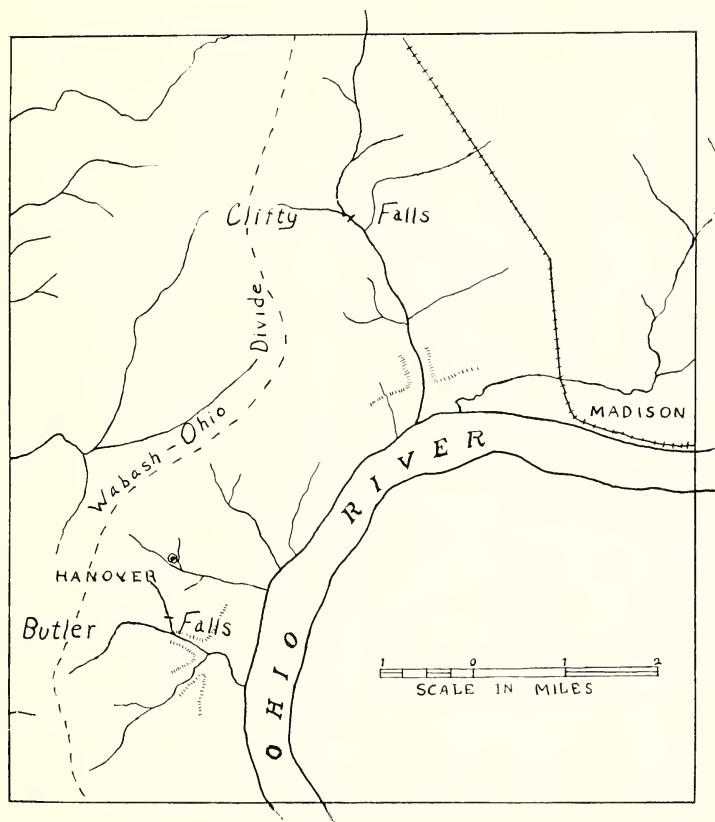


Fig. 2—Part of Jefferson County, Indiana, showing location of Clifty and Butler valleys.

An observation of the amount of sapping under Butler Falls seems at first to lead to a very different figure. During the 30 years it has retreated only thirteen-sixteenths of one inch through the same rock and in the same direction that Clifty Falls has retreated. At that rate it would have required approximately 1,600,000 years to retreat the 3,300 feet from the Ohio River bluffs. (Fig. 2.) However Butler Falls is in a short tributary of the main valley and the stream drains only about one-fourth as great an area as the main stream. So the retreat for nine-tenths of the distance was probably four times as rapid as the

present rate of retreat. The time in years would be about 400,000, which would seem to indicate that the age of Butler Valley is about that of Clifty Valley or possibly somewhat younger, and had its origin about the time of the Illinoian ice advance.

NOTES ON SOME OHIO RIVER TERRACES.

J. ARCHER CULBERTSON, Shortridge High School, Indianapolis.

Some of the best developed alluvial terraces to be found in the central states are located along the Ohio River where it forms the southern boundary of Indiana. A typical development is found in Jefferson County, Indiana, and Carroll and Trimble counties, Kentucky, where they are known as "first bottoms" and "second bottoms." The terms "third bottoms" and "fourth bottoms" would be applicable though they are not used.

These deposits, varying from a few feet to more than a mile in width, alternate on both sides of the river with steep bluffs which rise abruptly from the water's edge to a height of about four hundred feet. A bluff on one side is faced by a wide "bottom land" on the opposite side and vice versa, because of the swinging of the current from one side to the other. The length of each separate alluvial area varies from less than two miles to more than six, and the area ranges from approximately one-half square mile to more than four square miles. (Fig. 1.)

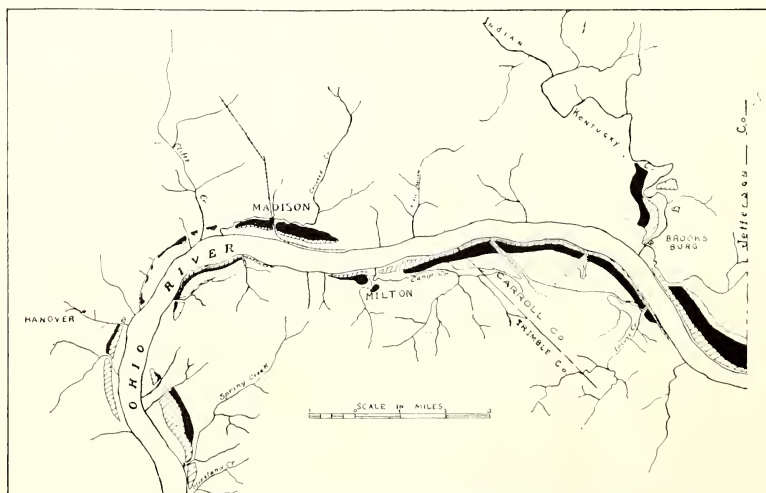


Fig. 1—Parts of Jefferson County, Indiana, and Carroll and Trimble Counties, Kentucky, showing area and location of terraces.

Diagonal lines // // // terrace number one.

Solid black ——— terrace number two.

Stippled terrace number three.

Area between diagonal lines and the Ohio River represents flood plain.

East of Madison there are three well developed terraces and south, with one locality excepted, there are only two. The flood plain varies in width from a few yards to more than a quarter of a mile, being wider as a rule where there are only two terraces. One terrace can be said to have the greatest area in all localities, though the largest single expanse is covered by the third or uppermost terrace, east of Milton, Kentucky.

Using the Ohio River as a datum plane and correcting the error caused by its rise and fall by observing the U. S. Government River Stage Report, the following elevations were obtained by use of an aneroid barometer. A bench mark on the Madison courthouse steps has an elevation of 500.725 feet, and the river at a ten-foot stage is approximately 420 feet above sea level.

The elevations taken in Jefferson County, Indiana, are as follows:

	Jefferson-Switzerland		
	County Line	Madison	Hanover Landing
River.....	430 feet	424 feet	420 feet
Flood plain....	460 feet	458 feet	455 feet
First Terrace..	480 feet	475 feet?	465 feet
Second Terrace	510 feet	508 feet	490 feet?
Third Terrace..	550 feet	absent	absent

The following are the elevation records taken in Carroll and Trimble counties, Kentucky:

	4 miles east of Milton	2 miles west of Milton	5 miles south of Madison
River.....	430 feet	425 feet	420 feet
Flood plain....	460 feet	460 feet	455 feet
First Terrace..	480 feet	477 feet	475 feet
Second Terrace	510 feet	510 feet	492 feet
Third Terrace..	555 feet	544 feet	absent

These elevations show that the top of the first terrace is usually from 15 to 20 feet above the elevation of the flood plain and from 40 to 50 feet above the Ohio River at a ten-foot stage. The second terrace rises about 60 or 70 feet above the flood plain and from 15 to 50 feet above the first terrace. The third terrace when present has an elevation of 85 to 95 feet above the floor plain and 15 to 20 feet above the second terrace. The exact level was difficult to obtain in some cases; however, it is easily seen that the Ohio Valley is filled with alluvial deposits 40 to 100 feet above the level of the present flood plain. These same deposits also reach a depth in some localities of at least 100 feet below the level of the flood plain. (Fowke, Ind. Acad. Sci. Proc. 1924, p. 90.)

The terraces are found to slope with the present stream, with the rate of slope slightly greater than that of the river at present. A profile across the terraces shows that they slope gently away from the river. Often that part adjacent to a higher terrace is low enough to be swampy and it probably formed a slough through which a portion of the flood waters passed at one time. The edges of the terraces were probably

built up when they were flood plains as natural levees are now being built. (Fig. 2.)

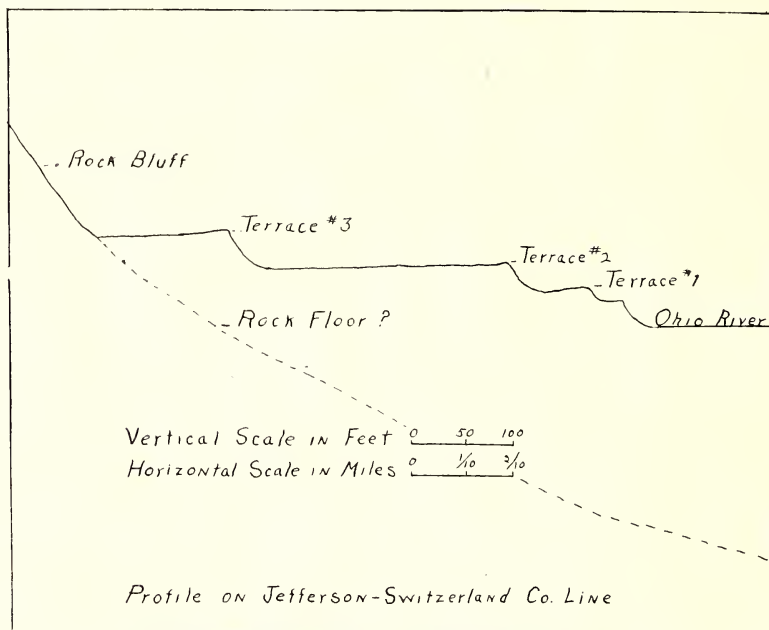


Fig. 2—Profile on terraces at Jefferson-Switzerland County line.

These deposits are composed of varying proportions of cross-bedded gravel, sand and clay. In most places they are covered by two or three feet of excellent sandy loam, though occasionally it is too sandy or too gravelly to be used for farming. In many places the gravel is suited for use on roads without any necessity for washing. On the farm of W. W. Walker, one-half mile south of Hanover, the overlying soil is mixed with the gravel and used on state highways. The soil helps pack the gravel but is somewhat objectionable on account of the dust it forms during dry weather. One portion of the pit contains gravel clean enough to be used for concrete. Most of the output is used for maintenance of highways and the state requirements for that purpose give a good idea as to the size of the pebbles. Not more than 3 per cent should be retained by $1\frac{1}{2}$ -inch mesh and 96/100 per cent by a number 28 mesh. Although gravel pits are located in all three terraces and the flood plain, the larger and better pits seem to be located in the second terrace. The gravel would undoubtedly be used much more were its location, below the Ohio River bluffs, more convenient to a greater number of people. One pit in Madison has been abandoned because the gravel is so firmly cemented with lime that it cannot be used without crushing. There is an immense supply of gravel in this area but it is doubtful if the demand will ever be great. In two pits at Madison almost pure sand may be obtained.

This material which partly fills the Ohio Valley is undoubtedly glacio-fluvial in origin, and a part of the valley train carried from the melting edges of the late Wisconsin ice sheet. The presence of three terraces and the higher elevation of the top of the valley train upstream from Madison and the presence of only two terraces and lower elevation downstream from Madison may lend support to Fowke's theory of a major divide at Madison as the present Ohio was formed by the successive ponding and overflow of northward flowing pre-glacial streams. (Ind. Acad. Sci. Proc. 1924.) Such would at least suggest at least enough ponding to cause the valley to be more nearly filled with glacio-fluvial material above Madison than below. The terraces directly south of Milton, Kentucky, seem to be similar in elevation to those east of Madison, so from this line of evidence only, the divide would be located to the west of these deposits.

SOME INTERESTING PHYSIOGRAPHIC FEATURES OF THE UPPER WABASH DRAINAGE BASIN IN INDIANA.

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The writer* proposes to discuss a number of topographic features associated with valley development found in that portion of the Wabash drainage area in Indiana above Delphi. These features occur along the valleys of the Wabash, Salamonie, Mississinewa, Little and Eel rivers, Little Pipe and Pipe creeks, and numerous smaller tributaries of not only the Wabash River but also of the other above-mentioned major streams.

Except in a very few cases, the features to be discussed are found along or adjacent to the major stream valleys. Upon leaving the main drainage channels one comes onto a monotonously level till plain, the surface of which is in general little diversified. The area under discussion, however, is crossed by a number of lobate moraines, which give some diversity to the topography where they occur, and also determine to a large extent the regional direction of the streams.¹ The origin and character of these moraines have been discussed by Leverett, Mallot² and others and hence need not be given further attention here.

The subject of this discussion has to do with certain features which have been developed in and along valley ways set below the general level of the upland till plain.

To appreciate the position of these features it will be necessary to discuss briefly the conditions under which they were formed. In pre-glacial times the relief of northern Indiana was probably comparable to that of southern Indiana at the present time. With the advent of the Pleistocene glacier, however, the surface configuration underwent a profound change. Although the moving ice undoubtedly performed some erosion, its great work in this region was of a depositional character. Located in close proximity to the terminus of the glacier in its retreating stages, this region was greatly modified by the thick mantle of glacial drift that was deposited. Here was an upland bed-rock plain, with a relief of from 100 to 300 feet due to valley development, which was completely buried beneath a mantle of drift. This upland plain

* The writer wishes to thank Dr. Clyde A. Malott, Professor of Geology at Indiana University, under whose supervision this paper was prepared, for his kind assistance and many helpful suggestions.

Contribution from the Waterman Institute, No. 32.

¹ Chas. R. Dryer, *The Drift of the Wabash-Erie Region—A Summary of results.* 18th Rept. Ind. Dept. Geol. and Nat. Res., 1894, pp. 83-90. Note the map.

² C. A. Malott, *The Physiography of Indiana.* Handbook of Indiana Geology, pt. ii, 1922, pp. 104-112, 149-154, 255-256.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

surface, portions of which have been resurrected along the main valley of the Wabash, seems to have had an elevation of from 700 to 750 feet above sea level. Drift filled the valleys and spread over the bed-rock upland, completely mantling it. This condition largely prevails today.

As the glacier advanced over the region the pre-glacial erosion surface was buried beneath the drift. Then as the glacier retreated, depositing great amounts of debris, the floods of escaping waters first spread out over this newly constructed till plain, but later concentrated along certain lines of discharge. As soon as the waters became concentrated along definite channels erosion started, and soon the streams had cut deep valleys into the drift. These became superimposed streams, as they not only cut deeply into the drift but also cut their channels deeply into the much-diversified bed-rock surface beneath the mantle of drift, where this buried surface was not deeply covered. Examples will be cited later where these superimposed streams have cut narrow gorges through very resistant rock. We may, then, picture the Wabash Valley of glacial times as being very narrow at some places, where the waters rushed through a gorge, and quite wide at others where the stream crossed ancient buried valleys. In still others we may imagine it as a rock platform over which the torrents were sweeping, cleaning off not only the till but also weathered material which had been buried when the glacier first passed over the region.

The carving out of the valleys, the stripping off of the thick mantle of drift with the consequent resurrection of pre-glacial erosional features, and finally the alluviation of the valleys themselves were carried on by waters which escaped from the melting glacier and later from glacial Lake Maumee. These valleys have suffered but little alteration since, because the Wabash River of today is insignificant when compared with its great progenitor.

The topographic features to be discussed are of two classes: those features which owe their origin to the depositional work of the ice and the waters which escaped from the melting glacier, and those which owe their origin to the bed rock of which they are composed. The features of alluvial character are of either glacial or post-glacial origin, while the bed-rock features are pre-glacial or glacial. Some of the bed-rock features of pre-glacial times have been resurrected by the removal of glacial drift from off or around them, but many of them undoubtedly remain concealed by the mantle of drift. Some of these bed-rock features came into existence during the period of glaciation, resulting from the erosional work of the escaping waters, but it is believed that by far the greater number were in existence in pre-glacial times and have been merely resurrected and only slightly modified.

It is obvious that the Pleistocene glaciation has had a profound effect on the topographic expression of northern Indiana. The region as a whole is a great drift plain, but it is known that beneath the wide expanse of glacial drift occurs an ancient erosion surface, of which we are privileged to obtain only occasional glimpses where the heavy mantle of drift has been removed by stream action. It is from these occasional glimpses, especially of the bed rock, that we may hope to interpret the physiographic and geologic history of northern Indiana.

GENERAL DRAINAGE CHARACTERISTICS.

With its relatively low gradient and small volume, the Wabash River of today is but the vestige of a mighty river of the past which carried the waters from the receding glacier, and later those from glacial Lake Maumee, to the Mississippi. From Huntington* to Delphi the Wabash River flows in a valley which came into existence during the glacial period. In some places the valley is narrowly and deeply cut into the thick mantle of till; in others it is a broad, level flat, bounded on either side by high bluffs of drift, while in still others it is a rocky gorge. The lower portion of the valley is much older than the upper part, for as the glacier's concentric terminus receded to the northeast, the valley of the Wabash was as rapidly lengthened to furnish an avenue of escape for the waters from the melting ice. From the state line to Huntington, however, the Wabash flows in a post-glacial valley intrenched but slightly in the till, particularly in its upper reaches, and seldom reaching bed rock. When bed rock is exposed, as at a point two miles southeast of Huntington, in the vicinity of Markle both above and below the town, northwest of Bluffton, at Vera Cruz and near New Corydon, it is not due so much to the erosional work of the stream as it is to the fact that the bed rock lies very close to the surface.

From Huntington the old glacial valley of the Wabash continues to the northeast, but is now occupied by only a small stream, Little River, which is but little intrenched below the old valley floor. This stream strikes bed rock some six miles above its mouth and flows over it most of the way to its mouth. The original channel has been deepened somewhat by recent excavation. In the vicinity of Huntington there is an old erosion surface lying at or near the floor of the glacial valley as indicated by the numerous quarry openings and by the natural outcrops along the channel of Little River. This bed-rock surface has an altitude of about 735 feet above sea level,—an altitude approximated in many places along the Wabash River. Apparently it is an upland level of a peneplain character antedating the glacial period.

Just east of Lagro the Salamonie River joins the Wabash on what is probably a rock floor. Successively upstream one finds frequent rock cliffs and steep till bluffs. In the lower half of its course the Salamonie has intrenched itself from 50 to 75 feet below the upland level, while in its upper half the valley is wide and rather shallow, and reaches bed rock only at Montpelier and Portland. Notable examples of the steep till bluffs are to be found around Heiney's Bend³ in southern Huntington County.

The Mississinewa River enters the Wabash about one mile east of Peru. Along this river from its mouth to its source are to be found frequent outcrops of rock, which may be in the form of vertical cliffs, rock floors or sloping bluffs. The Indians named it well when they called it Mississinewa,⁴ meaning the "River of Much (or Great) Stones."

* For the location of the various places and features that will be mentioned in the following discussion, see figure 1.

³ Wm. M. Heiney, River Bends and Bluffs. Proc. Ind. Acad. Sci. 1900 (1901), pp. 197-200.

⁴ H. W. Beckwith, Indian Names of Water Courses in the State of Indiana. 12th Rept. Ind. Dept. Geol. and Nat. Hist., 1882 (1883), p. 39.

Like the Wabash, the Mississinewa flows through frequent rock gorges where the old stream has been superimposed on the ancient pre-glacial bed-rock surface. Its valley is always narrow and well entrenched below the upland.

Little Pipe Creek empties into the Wabash River just west of Peru. Although a small stream, it has been able to cut a gorge through one of the ancient bed-rock coral reefs⁵ and also has cascades in its lower portions. The valley above Wallick's Mill where the gorge is present is broad and shallow.

Pipe Creek enters the Wabash River just below Lewisburg over bed rock of Kokomo age. Not far from its mouth a rock gorge begins and extends upstream to the present falls. The site of the present falls is over two miles from the Wabash, but the gorge is only about one-fourth of a mile long. Above the falls for a distance of a fourth of a mile the stream flows over a bed-rock floor of Devonian age. Except near Bunker Hill, Mier and Sweetsters where rock is found in the stream bed, the stream is in the drift.

Eel River enters the Wabash at Logansport over a rock bed. From Adamsboro to Logansport, a distance of some six miles, the stream flows over bed rock most of the way. Above Adamsboro no bed rock is seen.

The valleys of the smaller tributaries are always shallow and broad in their upper reaches and narrow and deep adjacent to the larger streams. Along the Wabash, Salamonie and Mississinewa, where rock is exposed, the small streams almost without exception flow through rocky gorges to reach the valley floor of the main stream. It is also a very common thing to find the streams tumbling over waterfalls near the river bluffs. If the stream is intermittent or very small the falls will be near the river bluff and an amphitheatre-shaped canyon head will be found, but if the stream is a fair sized one the falls may be back half a mile or more from the river bluff.

The major valleys of the Wabash, Salamonie and Mississinewa rivers were carved out in glacial times and have suffered little alteration since. The smaller tributary streams, however, have come into existence since the period of glaciation and hence have found themselves out of adjustment with the major streams. Where bed rock is present these post-glacial streams have not been able to adjust themselves very rapidly. In the till, however, they have cut down very rapidly. We may, therefore, expect to find tributary stream valleys of two kinds: (1) those which are developed entirely in the drift, having a broad, shallow poorly-defined upper portion, and a lower portion characterized by a narrow bottom with a high gradient, and steep valley sides; and (2) those developed partly in the drift and partly in the rock, having narrow, rocky defiles, with falls and cascades, in their lower portions, and broad, shallow depressions, developed in the glacial drift, in their upper reaches.

Stream valleys of the first class are well developed in the river bluffs and adjacent upland along the wider stretches of the Wabash Val-

⁵ E. R. Cumings and R. R. Shrock, The Silurian Coral Reefs of Northern Indiana and Their Associated Strata. *Proc. Ind. Acad. Sci.* 1926 (1927), pp. 71-85.

ley as at "The Prairie" near the Wabash-Miami county line, and in the vicinity of Peru. Examples of streams having valleys of the second class are Liston, Lagro, Charley, Treaty, Enyert and Pipe creeks.

TOPOGRAPHIC FEATURES OF THE VALLEY FLOOR.

When the great floods were debouching from the melting ice, the Wabash River undoubtedly spread out over its entire valley flat, as we know it today, in the form of a much-braided stream. Numerous islands of bed rock and bars of sand, gravel and drift stood up above the water level. With the reduction in volume of the Wabash River, due to the withdrawal of the ice, the waters became confined to much smaller channels, and since that time have cut for themselves rather narrow channels set below this old valley floor. This old valley flat in places now forms alluvial terraces, above which rise low ridges of sand and gravel that represent the sand and gravel bars of the ancient braided river. In like manner there are to be found frequent isolated rock masses standing well above the present flood plain. Finally the old channels which the water once followed now appear as streamless stretches from 15 to 25 feet above the present bed of the Wabash River. During the 1913 flood many of the above-mentioned terraces and abandoned channels were inundated.

This old valley floor is usually broad in its stretches of alluvial and glacial materials and rather spectacularly narrow where it is confined within rock gorges. The rock which has been removed from the gorges apparently formed obstructions to the off-flowing glacial waters. It is probably because of these obstructions in the valley that wide stretches between them possess alluviated levels attained temporarily, and which are now above the present bed of the river. As soon as the rock barrier was removed the stream cut down through the fluvial deposit, leaving it as an alluvial terrace well above the stream channel. Some such condition as this may have been responsible for the formation of such a feature as "The Prairie" in Wabash County, about which more will be said later.

An excellent example of the bed-rock floor of the ancient Wabash River is found in the vicinity of Delphi, where the rock lies very near the surface over a considerable area. Again east of Logansport on the south side of the river the bed rock is seen exposed over a broad expanse. Above this flat rise small isolated masses of Devonian and Silurian rock, representing the unreduced portions of this water-swept surface—perhaps those portions which stood above the swiftly moving waters as small islands. Over this surface strewn with the larger glacial debris rushed the torrents which had issued from the melting glacier above. Thus we find here a unique physiographic feature, which Professor Malott, upon first seeing, described as "a torrent-swept floor, above which rise isolated masses of unreduced rock—a feature caused by fluvial erosion and subsequently modified by weathering." In the vicinity of Huntington the bed rock lies very near the surface in the old glacial sluiceway, indicating that a feature similar to the one just described was formed here also. These torrent-swept rock flats, with their

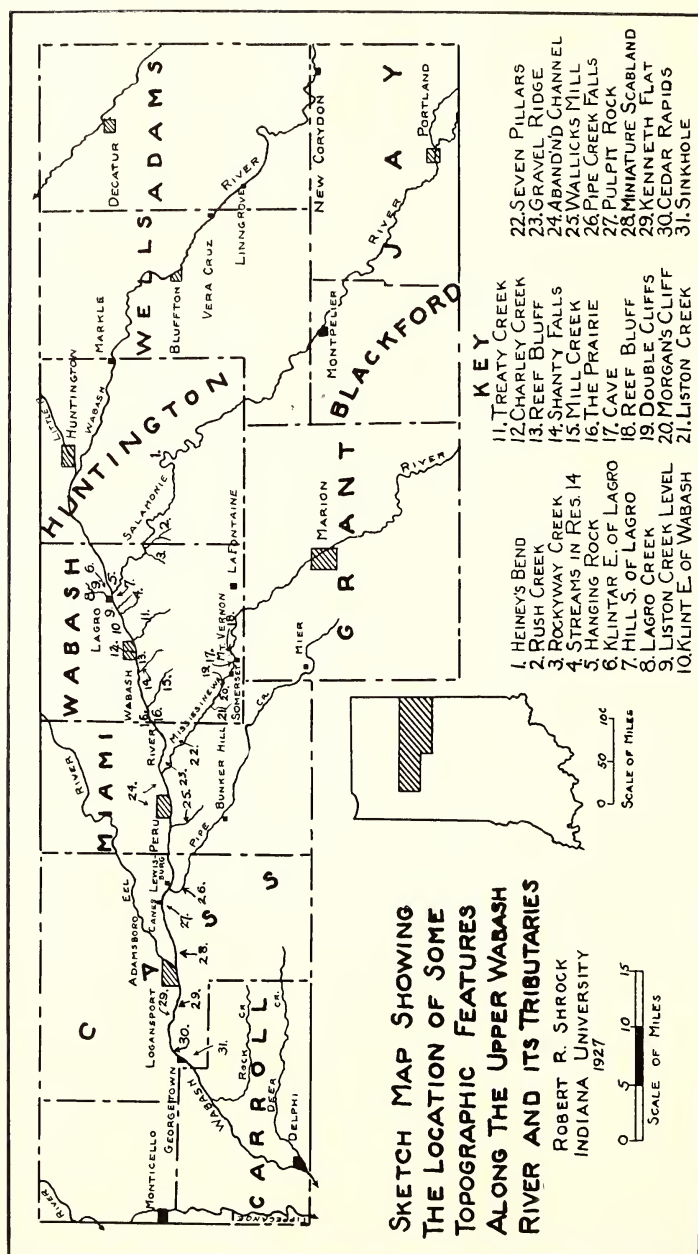


Fig. 1—Sketch map showing the location of some topographic features along the upper Wabash River and its tributaries.

interlacing channels and mound-like masses of unreduced rock, bear considerable resemblance to what Bretz⁶, has called "Scablands" in the Columbia Plateau. Their origin seems to have been much the same. The meager exposures of this torrent-swept flat in northern Indiana indicate, however, that even in its largest aspects it can be little more than a miniature "scabland."

Usually the unreduced portions of this miniature "scabland" appear merely as irregular piles of rock, but in reality they are actually bed-rock features which are weathered and broken only on the outside—a condition subsequently attained. One of these erosion remnants, located

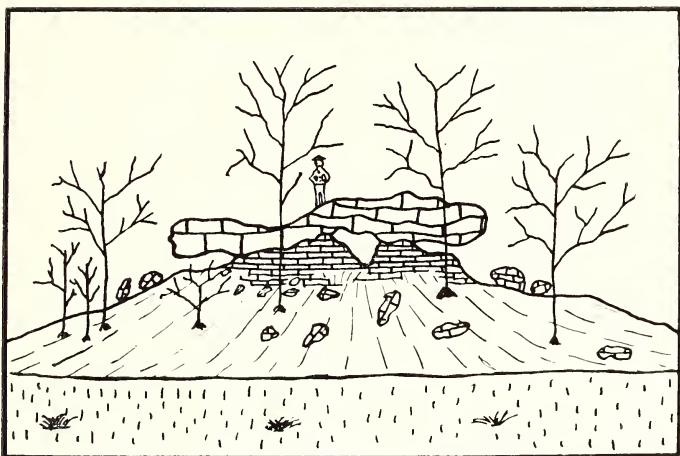


Fig. 2—Sketch from a photograph of "Pulpit Rock," near Danes (Cass County), Indiana. This erosion remnant stands about 20 feet above the surrounding valley flat. The man standing on the feature is six feet tall.

just south of Cass Station (Danes) some five miles east of Logansport, is of particular interest. On this bed-rock surface of fluvial erosion we find a feature which is thought of as characterizing a driftless area instead of a glaciated area. This feature, known locally as "Pulpit Rock," consists of a large mass of Devonian limestone perched on a narrow base of Kokomo limestone. Numerous holes are present at the contact, causing the large overlying mass to rest on a number of small pillars of Kokomo limestone. "Pulpit Rock" stands about 20 feet above the surrounding flat and is about 60 feet across the base and 30 feet across the top. It is elongate in the direction of stream flow. The figures given above are for the length of the feature. Its width is about half its length. The accompanying sketch (fig. 2) indicates the unique character of this unexpected feature.

⁶ J Harlen Bretz, *Glacial Drainage on the Columbia Plateau*. Geol. Soc. Amer., Bull., vol. 34, 1923, pp. 573-608.

⁷ J Harlen Bretz, *The Channeled Scablands of the Columbia Plateau*. Jour. Geol., vol. 31, 1923, pp. 617-649.

In the vicinity of Lagro two pronounced flats are present. The upper one represents a pre-glacial rock upland, which may be correlated with that revealed in the vicinity of Huntington. The lower level represents the torrent-swept flat developed by the discharged glacial waters at the expense of the pre-glacial rock upland. Rising above the lower flat, sometimes to the level of the bed-rock upland, are numerous irregular-shaped mounds of rock which are the unreduced portions of the upland.

One of these erosion remnants is of considerable interest. This hill, located about half a mile south of Lagro, is about 700 feet long, 300 feet wide, and rises 25 or 30 feet above the surrounding flat. It is elongate in the direction of stream flow in the Wabash River. The upstream end of this feature is rather abrupt but the downstream end is gently sloping. An examination showed this hill to be composed of Mississinewa shale⁸ mantled with drift.

At the south side of the broad level expanse where the Mississinewa empties into the Wabash is an oblong hill, with the longer axis lying in the direction of stream flow in the Wabash, which is probably of gravel and represents a remnant of a former gravel bar in the glacial Wabash. Between this hill and the south bluff of the valley is a streamless channel some 500 feet wide connecting the broad valley flat of the Wabash directly with the present channel of the Mississinewa.

The abandoned channels already mentioned are intimately connected in physiographic history with the terraces and erosion remnants. These channels were at one time the avenues of escape for some of the glacial waters, but have long since been abandoned and now appear as streamless valleys. Such channels have been noted five miles west and five miles east of Logansport on the south side of the Wabash River; in the vicinity of Waverly, eastern Cass County⁹; on the north side of Peru; near the Winter Quarters and at Double Cliffs along the Mississinewa; and south of Lagro between the Wabash and Salamonie rivers. Careful topographic mapping would undoubtedly show many more. During the great 1913 flood the waters followed a number of these channels.

The Prairie. Reference has already been made in a general way to the alluvial features that characterize the floor of the Wabash River Valley. These terrace-like features have been very carefully mapped by Dryer,¹⁰ but he neither described them nor offered any explanation of them or of numerous features associated with them.

A large area known locally as "The Prairie," located just east of the Miami-Wabash county line on both sides of the Wabash River, comprises one of these features. The main flat lies from 10 to 25 feet above the present stream level and is characterized by black fertile soil. It is mostly above the annual flood-water level, but in times of very high water, as in 1913, the greater portion may be inundated. Rising above

⁸ Cumings and Shrock, *Ibid.*, p. 72.

⁹ C. C. Beals, Soil Survey of Cass County, Proc. Ind. Acad. Sci. 1918 (1919), pp. 187-188. Note the map.

¹⁰ Chas. R. Dryer, The Maumee-Wabash Waterway. Ann. Assoc. Amer. Geographers, vol. IX, 1920, pp. 41-51, Fig. 8.

the main flat are numerous mid-valley, terrace-like remnants or elongated, flat-topped ridges of sand and gravel. These features are often 25 feet above the main valley floor or "The Prairie" and upon them are located the farm buildings of the region. Dryer seems to have interpreted these ridges as being of rock instead of alluvium, for he has shown them as such on his map. These ridges, elongate in the direction of stream flow, were probably at first great sand and gravel bars when the flood waters from the receding glacier were sweeping over the level which now comprises "The Prairie." Later they became islands even as they are today in times of exceptional floods.

"The Prairie" is between four and five square miles in extent. The level of the tops of the isolated ridges may represent a temporary gradation plain the height of which was determined by an obstruction farther downstream. As the obstruction was being removed the stream was cutting down through the drift which had been deposited, and finally a second level was established over which the glacial flood waters poured. This level is now the main valley flat or "The Prairie." Then when the waters finally subsided to the present volume of the Wabash, they became concentrated along a rather narrow channel and this ancient valley floor was left high and dry.

This broad expanse of low lying land is bounded on both the north and south sides by high till bluffs. Bed rock is not exposed anywhere within the area. It is altogether likely that the glacial Wabash crossed an old pre-glacial valley at this point and not being restricted by rock on either side was able to laterally extend its valley to an exceptional width. It is this broad valley floor that is called "The Prairie."

Reef Hills and Reef Bluffs. Scattered throughout the Wabash Valley above the junction of the Wabash and Tippecanoe rivers are numerous dome-shaped rock hills which have elsewhere been shown to be the remnants of ancient coral reefs.¹¹ These reefs may be partly or entirely exposed as rock hills, or they may form bluffs along the streams. Reef hills or mounds of a similar character in Gotland are called "Klintar" (singular—"Klint").^{12, 13}

One of the finest examples of these "klintar" occurs just south of where State Road 24 crosses the Wabash Railroad one mile east of Lagro. The north, east and south sides of the hill, which is elongate, slope with the inclined strata like the sides of an inverted bowl. The west side of the hill, which is the downstream or lee side, is concealed by a narrow tongue of drift which extends downstream from the rock hill. The reef mass has formed an obstruction in the path of the stream and consequently has protected the drift on the lee side from erosion. The rock mound or "klint" is about 450 feet in diameter and stands about 45 feet above the valley flat. The top of the hill is uneven. The tongue of drift extending downstream from the rock hill is 800 feet long. Nearby to the east are two similar "klintar," one of which has

¹¹ Cumings and Shrock, *Ibid.*, pp. 77-85.

¹² Carl Wiman, Ueber Silurische Korallenriffe in Gotland. Bull. Geol. Inst. Upsala, vol. 3, 1896-1897, pp. 311-326.

¹³ A. W. Grabau, Principles of Stratigraphy, 1913, pp. 420-430.

a tongue of normal stratified rock extending downstream for some distance from the reef mass. These hills form striking topographic features on the flat plain above which they rise.

Again about one mile east of Wabash, between the Wabash Railroad and State Road 24, is another of these "klintar." This hill is about the same size as the three already mentioned, but is not so high nor does it have such steep slopes except on the south side.

It is quite probable that the Cincinnati Arch in the regions under discussion was covered not only with Devonian and Silurian but also with Mississippian and Pennsylvanian formations, but through the long ages that elapsed between the close of the Paleozoic and the beginning of the Pleistocene, the forces of denudation had removed all the formations down to the upper Niagaran. Before the great continental glacier overrode northern Indiana there were undoubtedly many of the reef hills to be seen. It is quite likely that most of these now lie buried beneath the drift. We are privileged to see but a very few of them and these seldom in their entirety. Because of their great resistance to weathering and erosion, these reef masses have been able to exist not only through the long ages that preceded the glacial period, but even through the time that has passed since, and it is quite likely that except for some reshaping they have changed but little since the glacier passed over them.

The more spectacular of these "klintar" or reef hills are the four already mentioned, together with the ones at Hanging Rock near Lagro, and at the mouth of Mill Creek in western Wabash County. The accompanying sketch (fig. 3) shows the character of Hanging Rock, which rises over 75 feet above the level of the river.

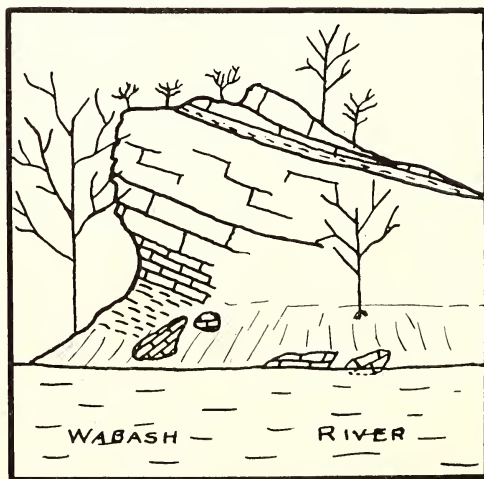


Fig. 3.—Sketch from a photograph of Hanging Rock, one mile southeast of Lagro, Indiana. This rock remnant is over 75 feet high and represents a "klint" formed from the unreduced portion of an ancient coral reef. The core of the reef was to the left of the picture. The Wabash River flows at the base of this feature.

Many reefs are only partially exposed in the numerous stream bluffs. One very interesting one occurs near Mt. Vernon, Wabash County, on the south side of the Mississinewa River east of the bridge. The cliff here is nearly vertical and shows a tangential section of a reef. The erosion of the centuries seems to have had no appreciable effect on this gray, somber cliff. Another reef cliff of considerable interest is found one-eighth of a mile east of Shanty Falls and about a mile west of Wabash, on the south side of the Wabash River. Here a great cliff, over 40 feet high in places, extends for over 1,000 feet along the valley. The cliff is very effectively described by Elrod and Benedict¹⁴ in the following words: "The massive wall of the outcrop rises in a sheer precipice forty feet high by one thousand feet in length. Its dark and frowning front, covered with gray lichens, looks as if only eternity could reduce it to dust." Numerous vacuities and large cave-like holes give a fantastic appearance to the ragged, towering cliff. Here and there along the bluff are small ravines down which the streams cascade in time of heavy rains. Accumulations of debris are found below them on the talus slope.

There are, in addition to the ones already mentioned, numerous other partially exposed reefs; but space does not permit a discussion of them here.

Some Features of the Pre-glacial Bed-rock Surface. Mention has already been made of a pre-glacial bed-rock surface. It remains to point out a few places where certain aspects of this surface may be studied. At the horizon of the Kenneth limestone¹⁵ in Cass County west of Logansport there is a marked flat developed over a broad area. This same flat is also developed at the same elevation on several remnants of pre-Kenneth age, indicating that it is an old erosion plain rather than a structural plain. It is believed, however, that the Kenneth limestone by virtue of its rather resistant character has been responsible for the preservation of a considerable expanse of flat upland surface of pre-glacial age. The glacial drift has been cleared from it, making it rather conspicuous. This flat is well developed west of Logansport on both sides of the Wabash Valley. Numerous outcrops of the white Kenneth limestone mark it, giving prominence to it as a topographic feature. It is quite probable that this flat, like the miniature scabland east of Logansport, was swept clean of its glacial debris by the torrents which rushed over it in the early history of the Wabash Valley. The town of Kenneth, from which the limestone is named, is located on this plain. The general elevation of the plain is about 650 feet above sea level.

From Wabash nearly to Lagro on the north side of the Wabash River just north of the Wabash Railroad, and again east of Lagro on the same side of the river for several miles, extends a rock bench which is developed at the base of the Liston Creek limestone.¹⁶ It is easily detected where the glacial drift has been removed. It is believed that this plain or bench is a representative of the same topographic level as

¹⁴ Moses Elrod and A. C. Benedict, *Geology of Wabash County*. 17th Rept. Ind. Dept. Geol. and Nat. Res., 1892, p. 214.

¹⁵ Cumings and Shrock, *Ibid.*, p. 77.

¹⁶ Cumings and Shrock, *Ibid.*, p. 75.

the one in the vicinity of Huntington developed at the same horizon. Both form remnants of a once more extensive erosion surface, most of which lies buried beneath the drift. The elevation of the plain in the vicinity of Lagro is about 735 feet above sea level. Here again the pre-glacial upland surface, developed at a particular horizon, has been preserved because of the character of the rock. Here, also, it simulates a structural plain.

TOPOGRAPHIC FEATURES OF THE VALLEY SIDES.

River Bluffs. Steep bluffs of both rock and till are frequently met with along the main streams. Mention has already been made of the reef bluffs, but there are also bluffs of normally stratified rocks. Some of the rock bluffs are precipitous, while others are gentle slopes. The till bluffs are in many instances remarkably steep. In fact, in a number of cases the writer had difficulty in ascending them after he had gone down them to the stream level. Around Heiney's Bend on the Salamonie and two and one-half miles west of LaFontaine and near "Seven Pillars" on the Mississinewa are to be found fine examples of these high, steep bluffs, often exceeding 65 feet in height.

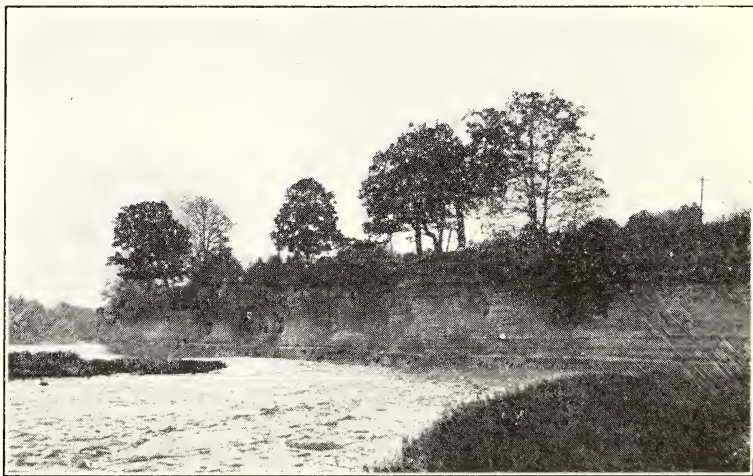


Fig. 4—View of "The Cliffs" or "Seven Pillars", along the Mississinewa River, three miles southeast of Peru, Indiana. This beautiful cliff is carved out of the Liston Creek limestone and is about 20 feet high.

The rock cliffs form conspicuous features along some of the streams. It is not an uncommon thing along the main rivers to see a vertical cliff from 25 to 75 feet high surmounted with gnarled cedars which hang over the bluff by roots that have penetrated the openings and cracks in the strata.

Owing to the well developed jointing and bedding of the Liston Creek limestone, very interesting features are often carved from this

formation. At "The Cliffs" or "Seven Pillars," three miles southeast of Peru along the Mississinewa River, the north bluff of the river is carved into a series of beautiful buttresses and alcoves, nicely rounded and swept clean of unsightly talus accumulations by the flood waters of the river. The accompanying photograph (fig. 4) shows something of the spectacular beauty of this interesting bluff. Several beautiful columns were also noted at Shanty Falls in the weathered cliff of Liston Creek limestone.

Upon thorough examination there are found to be a surprisingly large number of rather high rock bluffs along the Wabash, Salamonie and Mississinewa rivers. Without these fine exposures the stratigraphy of northern Indiana would have to remain forever an unsolved problem. Some of the more spectacular of these bluffs occur near Lagro along both the Wabash and Salamonie, in the vicinity of Wabash, and along the Mississinewa, chiefly in southwestern Wabash County.

Mention should be made of several rock gorges along the routes of the larger streams. One mile east of Georgetown at "Cedar Rapids" the Wabash flows through a rocky gorge, which has been cut through the core of one of the ancient coral reefs. At Wabash the Wabash again flows through a very narrow valley confined within high rock bluffs. At Double Cliffs, Morgan's Cliff and Somerset the Mississinewa flows through rocky gorges. In these cases the glacial streams have been superimposed on the old pre-glacial erosion surface and have cut through the rock where it happened to obstruct their path.

Waterfalls and Cascades. Low waterfalls and cascades are of common occurrence in streams entering the rivers. Most of the falls noted were developed at the contact of the Mississinewa shale and the underlying formation, which may be either Red Bridge¹⁷ or Liston Creek. The easily weathered Mississinewa shale overlain by the well-bedded Red Bridge or Liston Creek limestones gives rise to conditions favorable for the formation of waterfalls. These falls are of variable height, depending chiefly on the distance of the base of the Liston Creek above the valley flat of the major stream. Some of the better known falls of this type are Shanty Falls, 22 feet high, in a small stream one mile west of Wabash on the south side of the Wabash Valley; Liston Creek Falls, 5 feet high, in the bed of Liston Creek in southwestern Wabash County; and two beautiful falls, several feet high, in small streams one and one-half miles southwest of Lagro on the south side of the Wabash River in Reservation 14.

Several cases were noted where falls or rather cascades were present because of the presence of a coral reef in the stream channel. The streams have been unable to cut through the massive reef rock as rapidly as through the softer adjacent materials and cascades have been formed. Quite frequently the upturned edges of the inclined strata give rise to a series of beautiful cascades in the stream beds. Examples of this kind of cascade are found one mile north of Mt. Vernon, along the south bluff of the Mississinewa east of the bridge, where the water cascades about 20 feet along the steeply-inclined strata of a reef; at Rocky-

¹⁷ Cumings and Shrock, *Ibid.*, p. 74.

way Falls along Rockyway Creek one mile south of Dora; at Wallick's Mill on Little Pipe Creek, one and one-half miles southwest of Peru; and along Treaty Creek two miles southeast of Wabash.

Subterranean Drainage Features. Associated with the hanging valleys already described are features which owe their origin to subterranean drainage development. At Liston Creek Falls two small sinkholes were noted. The larger one was about 20 feet in diameter and at least 10 feet deep. The other was more like a swallow-hole. It had a small ravine extending out from the main sink. These sinks were located near the canyon a short distance above the falls. Just north of Mt. Vernon on the north side of the Mississinewa River west of the bridge a short distance is a small cave about fifteen feet long, seven feet wide and seven feet high. A smaller channel runs farther in from the room but it was too small for exploration. There is no water in this channel but nearby and about seven feet below, a good-sized spring comes out of the rock near the Liston Creek-Mississinewa contact. Just northeast of the spring in a small quarry the water can be heard flowing through the rock. This development, like that at Liston Creek Falls, is in the Liston Creek limestone. The formation is well bedded and has well-developed joint planes, both of which are favorable for subterranean drainage development. Small solution channels were noted in the bluff northeast of Somerset on the north side of the Mississinewa. Here again the development was confined to the Liston Creek limestone.

Two miles east of Georgetown, on the south side of the Wabash River, a farmer reported a large sinkhole about half a mile back from the river. He stated that in time of heavy rain considerable water goes into this sink. He also stated that under similar conditions water boils up vigorously at a much lower level in the flat along the river. It would seem very likely that the water which enters the sink comes out in the form of a spring on the flat adjoining the river. This development appears to be in the Kokomo limestone.

A very interesting case of subterranean diversion was noted along a small stream near the center of Reservation 14 east of Wabash. The stream formerly flowed over the surface in a well-defined but shallow valley to a falls where the water tumbled over to the canyon floor below. At the present time, however, the stream bed is dry from the falls upstream. About five feet below the crest of the falls, which are over the Liston Creek limestone, a large spring comes out at the contact of the Mississinewa and Red Bridge formations. The water seems to have found an underground route which is shorter than the surface route, and hence has abandoned the latter except in time of heavy rain when the subterranean channel can not accommodate all of the water.

It might be stated at this point that where conditions are favorable, springs are common at the contact of the Mississinewa shale and overlying formation. Because of the impervious character of the shale, the water, since it can not penetrate the shale, flows along horizontally until it can find an opening to the surface. In the Markland Avenue quarry at Kokomo and in the Erie Stone Company quarry at Huntington, large streams of water issue from the rock at the top of the Mississinewa shale.

SUMMARY.

The outstanding topographic feature of northern Indiana is the great till plain beneath which is buried an ancient pre-glacial erosion surface developed on a normal stratigraphic sequence which is interrupted at frequent intervals by complicated structures known to be ancient coral reefs. Crossing this broad till plain in a general westerly direction is the Wabash Valley with its major stream valleys of the Salamonie, Mississinewa and Eel rivers.

The Wabash Valley is a great sluiceway which came into existence during Pleistocene glaciation by the erosive work of the debris-laden flood waters which debouched from the melting glacier. Not only the Wabash, but also the Salamonie, Mississinewa, Eel and Little rivers are superimposed streams which have cut down into and in some cases through the drift from 50 to 100 feet below the upland till plain. Their valleys may follow or cross pre-glacial drainage lines or they may be entirely a result of the erosive work of the glacial streams. The numerous topographic features which characterize the valley floor and sides may have been in existence previous to the glacial period, or they may have come into existence during glaciation. With the decrease in volume of the streams, due to the withdrawal of the ice, they confined themselves to rather narrow channels and have since cut down below the old flood plain level, leaving portions of it as alluvial terraces. The tributary streams found themselves out of adjustment with these main streams so that they were forced to tumble over falls to reach the valley floor of the major streams.

Thus in northern Indiana today we find set into the till plain a glacial sluiceway which was once filled with a great rushing torrent of debris-laden waters but which is now occupied by a rather insignificant stream that covers but a fractional part of the flood plain of its mighty progenitor. Along this sluiceway we are privileged to catch only occasional glimpses of the old buried pre-glacial erosion surface, pre-glacial erosional features, and features which came into existence during glaciation. With the aid of these few glimpses it is our problem to interpret, so far as we can with such a limited amount of knowledge, the physiographic history of this most complicated yet interesting region.

The writer has attempted to describe some of the more outstanding topographic features of the great Wabash sluiceway and also to interpret the physiographic history of some of them. Suffice it to say that the physiographic history of the Wabash Valley is not simple; in fact it is extremely difficult, and many features can not be satisfactorily explained until careful topographic maps are available. Finally, in this region lies one of the most interesting physiographic areas to be found anywhere in Indiana, and the solution of its many individual problems, an almost hopeless task with present facilities, will mark an important advance in the knowledge of the physiographic development of our state.

PHYSIOGRAPHY OF THE KANKAKEE REGION.

T. M. BUSHNELL, Purdue University.

The Kankakee region has often been called a "basin" and its sandy plains have been considered lacustrine deposits of a shallow glacial lake. It is well recognized that the drainage area of the Kankakee River includes a belt of outwash plain along the Valparaiso moraine and that its principal tributary—the Yellow River—flows through morainic country. It is also well known that the characteristic topography and soil features of the Kankakee, which are marshes and sand dunes, extend beyond the actual Kankakee drainage basin into parts of Pulaski, Jasper and White counties. The extensive sandy flats apparently vary little in elevation. In both flats and dunes the original water-laid sands seem to have been reworked by wind to the uniform fine sand texture.

Through the courtesy of Director Lieber of the Indiana Conservation Department and Mr. Denzil Dogget, Assistant State Engineer, we can consult certain unpublished data from the Kankakee Ground Water Investigations. Figure 1 is based on seven lines of levels the engineers

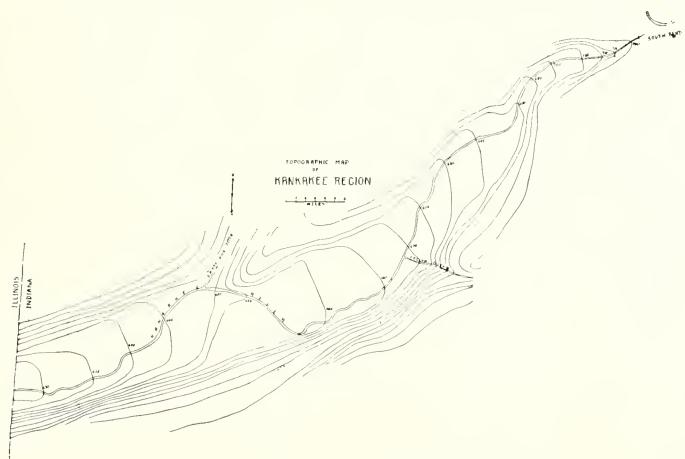


Fig. 1—Topographic map of Kankakee region in Indiana. Contour interval five feet.

have run across the Kankakee River region, approximately at right angles to its course. This gives a rough topographic map of the general features with all the detail due to sand dunes eliminated. This topographic sketch shows a flattish valley floor along the Kankakee River with a slope of about one foot per mile downstream. The outside bends of the river channel touch the borders of this flattish valley floor as stream courses normally do. Although the eye finds little resemblance to valley

walls or uplands along the Kankakee Valley, the elevations as drawn on this topographic sketch show distinct rises on each side. The engineer's profiles of each line look like cross-sections of a stream valley rather than of a portion of a lake plain. This valley has a width of about five miles at the state line, widening a little near old English Lake and narrowing to two or three miles near South Bend. It looks like the natural continuation of the St. Joseph River drainageway previous to the formation of its present deep outlet to the northwest.

The soil survey map of Porter County shows sandy lands which are continuous from the well-defined Glenwood beach, extending through a gap in the moraine at Valparaiso, with a broad channel leading from that point south to the Kankakee. This appears to be an outlet of glacial Lake Chicago when it stood about 80 feet above the present level of Lake Michigan. The Continental Divide passes through a muck area in this channel.

Perhaps some of the present lake-like plains were formed by sands drifting over higher till plains to form the dune-locked marshes. At some places along the southern border of the Kankakee region the "till uplands" appear to be lower lying than nearby "lake flats" which are enclosed by dunes rather than beaches.

THE LITTEN NATURAL BRIDGES AND CLOSELY ASSOCIATED PHENOMENA, EASTERN OWEN COUNTY, INDIANA.

ARCH R. ADDINGTON, Indiana University.

These interesting features of our state are rather remote from the main traveled highway and they are so deftly secluded by their immediate surroundings that the occasional explorer of the region usually fails to hear of their existence. My interest was first aroused in them while on a "cave hunting" trip in eastern Owen County during the summer of 1926. It occurred to me that the bridges and their immediate environment are of rather peculiar interest since they are located near McCormick's Creek Gorge and because the small drainage diversion associated with their development has taken place in a direction that is nearly diametrically opposed to the regional dip of the rock in the locality.

Consequently, during a few days in the summer of 1927 the region was studied more carefully. A few square miles were mapped on basis of a 20-foot contour interval and a smaller area near the bridges was mapped on basis of a 10-foot contour interval. Valuable assistance in completing the topographic mapping was given by Mr. S. T. Clashman, a student of Indiana University.

Location and Description. People of the local community refer to these features as the "Litten Natural Bridges," presumably because the bridges are located on the farm of Mr. Jack Litten.

The bridges, two in number, are situated close together near the upper end of a short, rocky gorge. They are found a few paces south of the by-road that may be noted crossing the northwest $\frac{1}{4}$ of section 14, township 10 north, range 2 west. (Fig. 1.) The bridges are $\frac{3}{4}$ mile north and east of McCormick's Creek Gorge and $\frac{7}{8}$ mile south and east of White River at the place where it bends to the west in section 11, township 10 north, range 3 west.

In the summer season the location of the bridges is almost obscured by the dense undergrowth of brush and tangling vines that everywhere are prevalent in this region. Most of the large timber has been removed, so that the entire locality is more or less a wild, woolly, thicket.

When dry weather prevails, it is possible for the motorist to drive along the by-road to the point where it is crossed by a small tributary stream to White River. (Fig. 1.) From this place it is only a few paces to the southwest until he will find himself in the small, steep-sided, rocky gorge. Cautiously picking his way around and over rock fragments that litter the rocky bed, it is only a short distance until the first of the natural bridges can be seen.

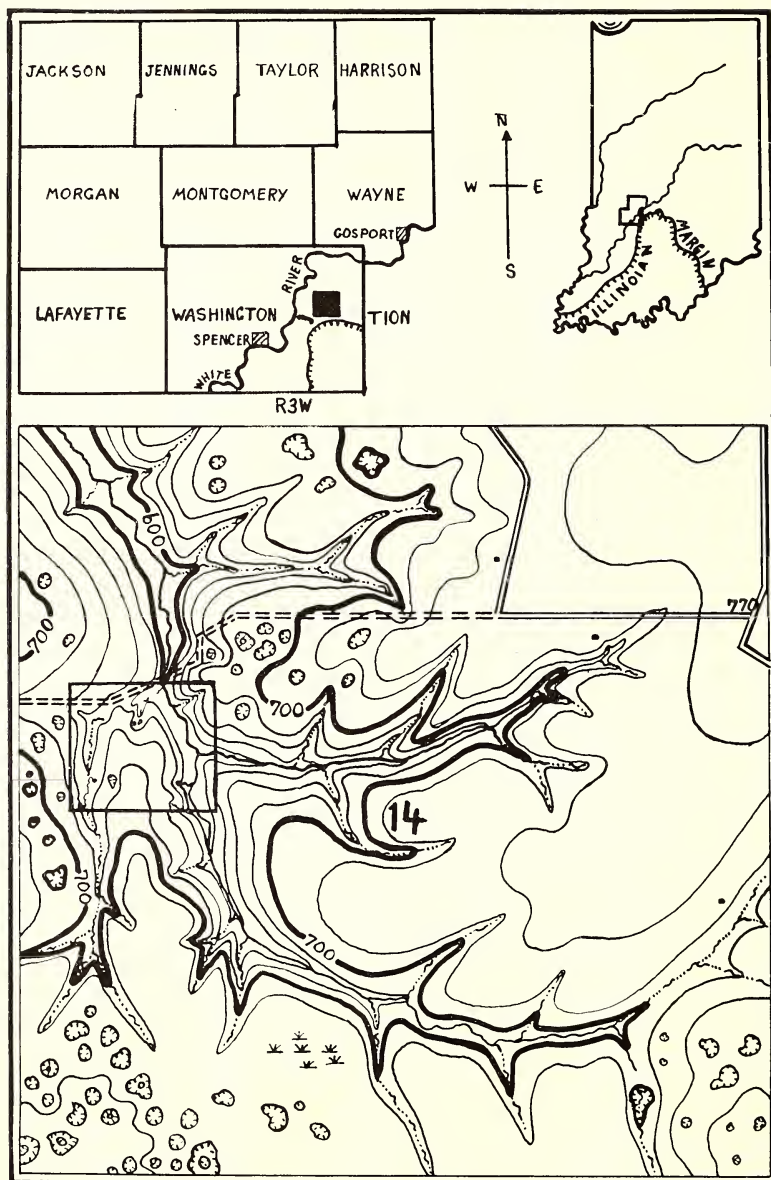


Fig. 1—Topographic map of section 14, township 10 north, range 3 west. The map shows the general topographic condition near the Litten Natural Bridges. The rectangle encloses an area reproduced as figure 2. Contour interval 20 feet.

The insets are maps of Indiana and a part of Owen County which illustrate the general locational relations of the region to the Illinoian Drift and to the principal drainage routes. McCormick's Creek Gorge is illustrated by a short black line in the inset of Owen County. Area topographically mapped indicated by black square.

It is picturesque. A rather massive limestone layer forms the span rock which has a total length of 15 feet. Its vertical thickness is four feet, width 10 feet, and its distance above the bottom of the gorge is 12 feet. The generalized cross section profile of the opening beneath the span is somewhat rectangular in outline but weathering processes and the erosive work of running water have undermined the bridge abutments to a considerable extent. The rock forming the bridge abutments is rather thin layered and somewhat crossbedded.

Immediately beyond the bridge the stream channel bends abruptly to the right. Some slumping of material from the sides of the gorge has occurred here and has partially obstructed the channel. As soon as one passes around the bend the second bridge may be seen. This is no less picturesque than the first although it is less in size. The channel beneath it is littered with rock fragments, some of large size, which seem as if they had only fallen yesterday.

The span rock is formed of the same massive layer as that of the first bridge and it is of the same thickness. The length of the span is 10 feet, the width six feet, and the height above the bottom of the gorge is six feet.

Associated Phenomena: From a vantage point on the rock fragments beneath the bridge one can gaze into a low cavern entrance made to appear lower than it really is because of the collapsed rocks that partly obscure its true dimensions. Just within the entrance there is a shallow pool of limpid water. A short distance farther on the roof becomes lower and cavern darkness prevents any further visibility by natural means.

If the visitor now climbs to the top of the bridge and then proceeds in a general westerly direction across a gently rounded spur of land he comes rather abruptly to a valley-like depression which terminates in a low broadly arched cavern entrance, not greatly dissimilar to the one he saw from his vantage point beneath the bridge. This cavern entrance leads to Wolf Cave and according to traditionary accounts the last wolf of the county met his fate here. It scarcely calls for any stretch of imagination on the part of the observer to see that this entrance leads into the same cave as that at the bridges. In other words, Wolf Cave is simply an irregular limestone tunnel with cavern-like entrances at either end. The distance the entrances are apart is approximately 200 feet.

At times, an intermittent stream flows in the valley, disappears in Wolf Cave, emerges from the entrance near the bridges, flows beneath the latter, and eventually joins the tributary stream in the valley adjacent. That this has not always been the case is evidenced by the continuance of the valley depression beyond Wolf Cave and the presence of a low col in the valley. A study of figures 2 and 3 will make clear existing and former conditions of drainage.

Proceeding up the valley in a general southerly direction from Wolf Cave a small spring may be noted issuing from the west side of the valley. The branch thus formed flows a short distance to the north and finally disappears among the rock on the east side of the valley.

The spring is not a large one and its volume diminishes considerably in dry weather. In local phraseology, it would perhaps be called a "wet weather" spring.

Farther south the valley divides into several sharp ravines that head upon a plain modified by numerous steeply funnel-shaped sink-holes. From these sinks it is $\frac{1}{4}$ mile to the gorge of McCormick's Creek, or more strictly speaking, the gorge is $\frac{1}{4}$ mile in a southwest direction from the southwest corner of the mapped area shown in figure 1. The property of the state park adjoins the area on the south and west.

It seems most reasonable to believe that the sinks found in this part of the section represent drainage through subterranean routes to the gorge of McCormick's Creek. That the subterranean drainage should follow the normal dip of the rock to the southwest rather than to some eastern point, as is the case farther down the valley, is because there is no deeply entrenched valley adjacent these sinks on the east. If the drainage through the sinks is to McCormick's Creek Gorge it is easy to see that the stream which at times flows through Wolf Cave is robbed of some of the water it otherwise would have. Diversion of surface waters through subterranean channels at the headwater portions of surface streams is not an uncommon phenomenon in limestone countries. A classic example of this is to be found in the Bloomington region where the headwaters of Indian Creek have been diverted through subterranean routes to the valleys of Clear Creek and Richland Creek.¹ Other examples might be mentioned. The general effect is to decrease the volume of the surface stream and thereby decrease the rate at which such stream may lower its valley. Although this is not the only factor involved it is an aid in establishing a difference in valley levels of a tributary to that of a larger stream. The intermittent stream flowing into Wolf Cave is suggestive of this condition. (Fig. 1.)

Attention is now called to the largest valley depression represented in the figure. (Fig. 1.) This valley continues in a generally north-west direction until it joins White River Valley about one-half mile distant. The stream which flows through this valley is fed principally by springs and seepage. It will be noted that the valley floor is considerably lower in elevation than that of the valley leading to Wolf Cave. (Fig. 2, which is mapped on basis of a 10-foot contour interval, illustrates the condition more clearly.)

In the southeast part of the area shown by figure 2, a spring may be noted issuing from the west valley wall. The volume of the spring is comparable to that which may be seen at the spring in the valley to the west. Between the places where the water from the latter spring disappears in the rock and the spring in the valley to the east one may note a steep sink hole that is almost on a line between the places mentioned. The condition just described is suggestive of a subterranean route beneath the spur separating the two valleys. It should be noticed that the distance separating the two places is not great, being approxi-

¹J. W. Beede. The Cycle of Subterranean Drainage as Illustrated in the Bloomington, Indiana, Quadrangle. Proc. Ind. Acad. Sci. 1910, pp. 81-111.

mately 30 rods. The general direction in which the diversion takes place, however, is to the east, which is opposite to the normal dip of the rock in this locality.

It will be noted with reference to the location of Wolf Cave and the natural bridges that the alignment is similar to that mentioned above and that the general direction of diversion has been to the east. Diversion opposite to the dip of the rock is, perhaps, more unusual than

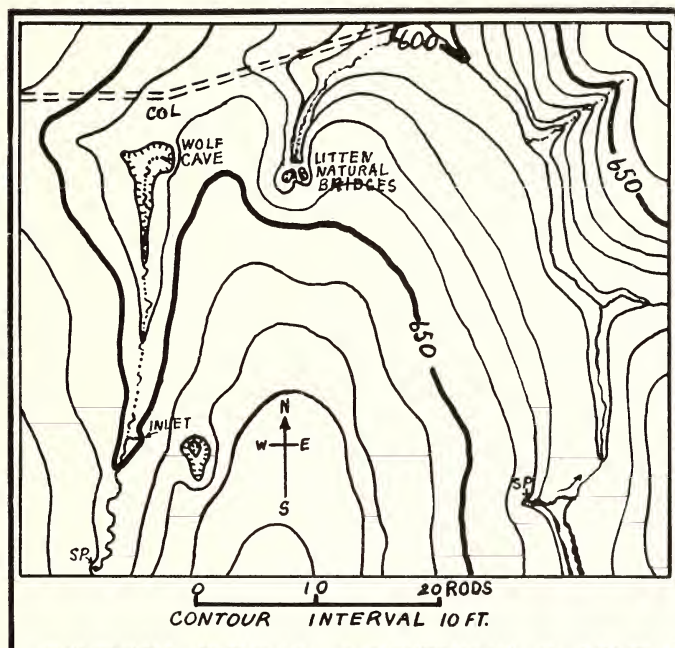


Fig. 2—A reproduction on a larger scale of the rectangle shown in figure 1. The positional relations of the cave, natural bridges, gorge, and abandoned valleys are shown. The figure illustrates successive abandonment of a valley by a surface stream due to subterranean diversion.

usual. Its development here is due to local conditions which will presently be explained. An important factor in bringing about the conditions of drainage shown here is the lithologic characters of the sub-surface rocks.

General Geology. The surface materials of the area are of glacial origin and consist of gravelly loams, silts, and sands such as one might expect about the waning borders of an ice mass. None of the glacial material is of large size and some of it could, perhaps, best be described as outwash. The general relation of the area topographically mapped to the Illinoian Glacial Margin may be observed by noting figure 1.

The bed rocks of the region exposed at the surface are Paleozoic sediments of Mississippian Age. The rock formations having surface

outcrop are the Mitchell Limestone and the Salem Limestone. The dip of these formations in this particular locality is toward the west at an average rate of 30 feet per mile.

The Mitchell Limestone forms the sub-surface rock of the higher elevations. Its lower limit in this area as determined by barometer measurement is 650 feet. The formation is one of the most conspicuous lithologic units of the state and its salient characteristics have often been described.² The individual layers of the stone are rather dense and their excessively jointed character make the formation most favorable for the circulation of subterranean waters when suitable conditions of topography are present. The sinkholes, previously mentioned, and also the sinkhole between the springs, are developed in this formation.

The Salem Limestone lies beneath the Mitchell Limestone and is the lowest rock formation exposed in the area. Core drillings indicate a thickness of 80 feet. The part used as a quarry stone is a massive bedded, nearly pure carbonate of lime rock. Where streams cut into the formation its massive character is oftentimes excellently represented by the cliff-like exposures along the stream valley. Such exposures are present in this region but the cliffs are not high and so fail to show upon the topographic map.

In many instances the upper part of the Salem, near its point of contact with the overlying Mitchell, is composed of alternate thin and thick beds, sometimes cross-bedded, and presenting more or less of a shaly character. This lithologic phase is usually referred to as "Bastard Rock" or "Rotten Rock" among the quarrymen. It is not uncommon for small springs to appear at this horizon, the water having circulated along the joints and crevices of the overlying Mitchell stone. The influence of this phase is represented by the appearance of the springs illustrated in the figures accompanying this paper. (Figs. 2 and 3.)

The natural bridges also occur in this part of the Salem formation. The span rock representing a relatively thick bed while the bridge abutments are carved from the thinner layers. (See description of bridges, page 143.) This lithologic condition has been favorable to the formation of the bridges and to their preservation.

Joints occur in the Salem Limestone. These are oftentimes of large size. The joints are rather widely spaced, however, and are not nearly so numerous as they are in the Mitchell Limestone. Where joints are present they exert an important control over the direction of flow of subterranean streams and where sufficient difference in adjacent valley levels exist the combination of these conditions may overcome the influence of regional dip of rock in controlling the general direction of sub-surface flow. It is evident these conditions must be present at the natural bridges and at the place farther south where diversion of spring waters is now taking place.

The general situation as regards the geology and topography of the region may be obtained from figure 3. From this figure the general

² Hand Book of Indiana Geology, pp. 499-508, Citation E. R. Cumings, for complete description of the Mitchell and Salem limestones.

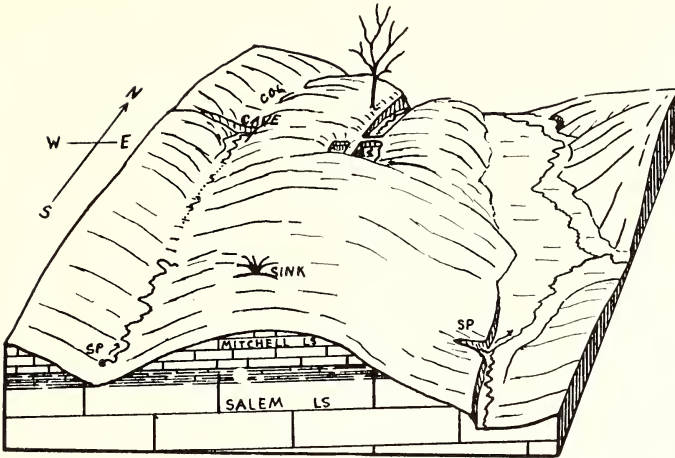


Fig. 3—A generalized block diagram illustrating positional relations of the rock formations and the general topographic condition. The dip of the rock formations and the vertical relief is slightly exaggerated. The finer divisions represented in the upper part of the Salem Limestone are to illustrate the thin layered and shaly phase of that formation.

positional relations of the rock formations may be observed as well as a bird's-eye view of the positional relations of the gorge, bridges, and cave.

In the immediate vicinity of the bridges the influence of glacial material can practically be neglected since it forms only a very thin veneer over the bed-rock.

It is assumed that the change of drainage associated with the formation of the natural bridges occurred in Post Illinoian Time, perhaps Post Wisconsin, an assumption that is based upon the very youthful stage of development of the gorge and the apparent recency of the drainage change.

The Drainage Diversion: Brief Résumé of Development. As a result of the survey of surface conditions in the area near the Litten Natural Bridges it appears that the intermittent stream, which at times flows into the cave, formerly followed a surface route to its point of junction with the larger stream in the neighboring valley. At this period the valley levels of both streams were at a higher elevation than now and it is probable their place of junction was at an accordant level. A condition of this character would not favor subterranean diversion of the water from the tributary to that of the larger stream because there would be no difference in static head.

The entrenchment of the area by streams was and is primarily dependent upon the entrenchment of White River. Hand in hand with the deepening of the valley of the latter would occur the deepening of its tributary valleys, tributaries to them and so on *ad infinitum*. But

if for any cause related to lithologic control, to stream condition as regards volume, velocity, and amount of load, one stream is able to deepen its valley faster than an affluent, it will in time leave the affluent at a higher elevation at their point of junction and as a result a waterfall or cascade may develop at the mouth of the affluent stream. It is not improbable that a waterfall or cascade developed here, but if such were the case, process and time have obliterated all tangible evidence of its former existence. A small valley depression extends in the general direction of the col (fig. 2) and is followed in part by the roadway.

Contemporaneous with the establishment of difference in level of adjacent valleys arises the favorable condition for an active subterranean circulation from the higher valley level to that of the lower valley level, particularly, if such valleys are formed in areas of pervious or well-jointed rock. Under a topographic condition of this sort the presence of joints and bedding planes in the rock mass form routes of least resistance for the circulating waters. Such routes may be rapidly enlarged by the swirling eddies that at times follow them and in time a tubular cavern may result. The water would appear from the lower end of such a tubular cave as a spring.

In time the inlet for the water becomes sufficiently enlarged so that it accommodates all the drainage of the valley above the point of inlet. Along with this enlargement goes, deepening of the inlet by the stream flowing into it and as a result a new and steeper gradient appears in the valley immediately above the inlet. Weathering processes and erosive work of running water cause a gradual recession of the cavern inlet in a general downstream direction. There is some evidence of this migration at Wolf Cave.

Changes also occur about the spring outlet. In many instances the volume of water issuing is able to remove the fragments of weathered material that otherwise would accumulate about the spring orifice and serve as protective covering against weathering agencies. The gradual collapse of material over the subterranean stream due to weathering about the spring outlet and to the erosive and chemical work of the stream in widening its channel and the subsequent removal of this material, in time, forms a gorge which gradually increases in length in an up-stream direction. The natural bridges span a small gorge of this origin. (Fig. 3.)

The cavern, gorge, natural bridges, and the abandoned part of the valley are topographic features that result from the drainage diversion through subterranean routes of the surface stream that intermittently occupies the valley leading to Wolf Cave.

Formation of Litten Natural Bridges. Natural bridges result from divers causes. It is beyond the purpose of this paper to present a résumé of natural bridge formation, which would necessarily demand considerable space and time.³

³ H. F. Cleland. "North American Natural Bridges," Bulletin Geological Society of America. Vol. 21, pp. 313-338. An excellent summary of natural bridge formation.

The Litten Natural Bridges are the direct result of the partial collapse of adjacent portions of a cavern roof. This mode of origin is most evident since the bridges are in such close proximity to the vestige of cavern remaining. To walk beneath the bridges and then almost immediately into a cavern entrance suggests a method of origin too plain to be denied. Primarily, they owe their existence to those conditions which favored differential deepening of adjacent valleys and to the subterranean circulation which was thereby established.

The method of natural bridge formation by collapse of adjacent parts of a cave roof is not unusual. It is a method described in nearly every text book dealing with the origin of land forms. But these bridges are of particular interest because they are so closely associated with the attendant phenomena that furnish undeniable evidence of their method of origin. Such a clear case of this manner of natural bridge formation is perhaps not equalled in very many localities.

Significance of Features and Phenomena Described with Reference to McCormick's Creek Gorge. It will be recalled that the location of the bridges and associated features is within a fraction of a mile of McCormick's Creek Gorge, which is the chief attraction of the McCormick's Creek State Park.

Several theories have been advanced to explain the origin of this well known feature. The most probable of these, according to Mallott is, "that the canyon was begun by underground drainage since the structure and dip of the rock in which the gorge is located are favorable and such drainage would not be unnatural under such favorable circumstances."

Is it not suggestive to find within so short a distance of McCormick's Creek Gorge a smaller feature of similar character whose origin is so clearly demonstrated? Does not the presence of Wolf Cave, the Litten Natural Bridges, and the attendant gorge furnish evidence in corroboration of the subterranean theory of origin of the larger gorge? It may seem to some, perhaps, that the analogy is too far-fetched but the finding of these interesting features so near McCormick's Creek Gorge seemed to the writer a very significant piece of evidence pointing to the subterranean method of origin of the latter.

Although McCormick's Creek Gorge is developed in the Mitchell Limestone (the Salem Limestone is exposed near the lower end of the gorge) and the features herein described are developed in the Salem Limestone, it will be noted that the lithologic character of the material in which these features have been formed is not greatly dissimilar to that of the Mitchell Limestone. Because the features happen to be in different geological formations does not preclude the possibility of similar methods of origin.

⁴ C. A. Malott. Hand Book of Indiana Geology, p. 215.

AN ANALYSIS OF EROSION.

CLYDE A. MALOTT, INDIANA UNIVERSITY.

The chief purpose of this paper is to briefly present to the view of students and teachers a clear analysis of the common processes of land sculpture, and incidentally to give definition and precision to certain terms which are used with respect to the sculptural processes. The subject matter deals with certain elementary phases of dynamic geology particularly encompassing the road over which all students of geological science travel in the secondary and college courses.

The literature dealing with the subject matter of this paper is very voluminous, and no attempt will be made here to cite references which cover all phases of it. Much of the literature deals with the common processes which have been presented over and over again in textbooks and other publications until the original presentations are not always apparent or available. Such terms as *weathering*, *erosion*, *denudation*, *corrasion*, and *corrosion*, have long been used. In certain early works they are used incidentally in describing the commonly observed processes and results of land sculpture. These terms are not used by all authors alike, with the result that considerable confusion with respect to their uses may be noted in the numerous elementary textbooks in our schools today. This confusion in the use of these common terms is most felt by instructors in the elementary courses.

Attention has occasionally been called to the confusion in the use of a number of the common terms used in elementary geology. One of the more recent of these protests against the confusion of the terms in our common textbooks is that of Malcolm H. Bissell¹ of Bryn Mawr College. Bissell cites J. W. Gregory's protest of 1911 in the *Geographical Journal* in which Gregory called attention to the various inconsistencies in the use of these common terms and suggested certain restricted uses of the terms. Gregory's suggestions have not been followed, and perhaps it is well that they were not, for the definitions offered by him are open to strong objection. Bissell cites the various uses of the terms as given in the leading texts that had appeared since 1911, and gives an admirable summary. He makes certain suggestions as to the use of these terms, and makes a plea that some responsible organization, such as the Geological Society of America, take up the matter of the use of these terms and give them standardized meanings. His presentation of this subject was read with much interest, and in two subsequent numbers of *Science* the use of the terms was discussed with suggestions which deserve consideration.²

¹ On the Use of the Terms "Denudation", "Erosion", "Corrosion", and "Corrasion", *Science*, N. S., vol. LIII, 1921, pp. 412-414.

² F. H. Lahee and W. G. Foye, *Science*, N. S., vol. LIV, 1921, pp. 13 and 130-131.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

It is not the intention of the writer of this paper to attempt to dictate what meanings shall be attached to the common terms of weathering, erosion, denudation, corrasion, corrosion, etc., so much as it is to present a clear analysis of the processes of erosion. Incidentally specific meanings are given these terms.

WEATHERING AND EROSION.

The terms weathering and erosion are very old terms—as old as the science of geology. They are much used terms. They are inclusive names for two sets of destructive processes which act upon the land material at and near the surface. Weathering is the group name for all the destructive processes which more or less statically act upon the materials of the land, while erosion is the destructive action of the moving or mobile agencies which act upon the lands. Together these two sets of processes bring about land waste or denudation, resulting in land reduction and restriction. Incidentally in land reduction or denudation, sculptural features, such as make up many of the landscape features of the lands, are produced. The features sculpturally produced are not permanent, but themselves undergo change and finally pass into nothingness in the final stages of land reduction. I am inclined to use the term *denudation* as comprehending both weathering and erosion. It has frequently been used in this sense, though for the past hundred years or more it has also been used incidentally as equivalent to the term erosion alone.

Weathering is the group name for all processes which carry on disintegration and decomposition of rock or rock materials at and near the surface, usually leaving crumbled or broken-down products as a result of the action. Rock or rock materials are disintegrated or decomposed *in situ* independent of removal agencies. The chief weathering processes concerned, acting singly or in conjunction, are: alternate freezing and thawing, wetting and drying, heating and cooling (without water), destructive work of organisms (mechanically and chemically, alive or dead), direct solution, hydration and carbonation (indirect solution), oxidation, and hydration. These processes along with some others not so well known act statically upon rock materials, with the result that rock debris or residue is formed at or near the places where the processes acted.

Some authorities (as for instance, Dana) would include as a part of weathering the incidental concentration of iron oxide, silica, or other substances, which shows on certain weathered surfaces, or surfaces undergoing weathering, as outstanding hardened places which give a fretted or rough appearance. These surfaces are frequently referred to as "honey-comb weathering." Such reinforcement of parts of rock surfaces undergoing weathering is carried on by processes which may accompany the weathering of certain rock surfaces, but these need not be included under weathering. Weathering processes are destructive. Efflorescence may cause a scaling off of material from certain rock surfaces, and when it does act in this way it should then be included in the weathering processes.

Erosion (Latin, *erodere*, to gnaw away) is the name applied to the initial work of the important moving agencies which acquire, transport and deposit earth materials. Through the agencies of (1) wind, (2) running water, (3) glaciers, and (4) waves and currents, earth materials are actively withdrawn from surfaces. These agencies also transport and deposit earth materials. A considerable part of the work of glaciers and streams (rivers) is that of transportation and deposition without erosion on the part of these agents to acquire the material, as a considerable part of their loads may have been contributed to them. A large part of the chemical load of a stream is undoubtedly contributed, and, since this part of the load is unlikely to be deposited by the stream, streams then become mere transporting agents. But it is the erosive phase of these agencies that is to be considered here. The taking up of earth materials or the active acquisition of them by the surface mobile agencies constitutes erosion. Erosion is the initial work of the mobile agencies acting on the land surface. The final work of these mobile agencies is that of deposition, and deposition is exactly the opposite of erosion. Erosion is subtractional with respect to surfaces, while deposition is additional. Transportation is a connecting process between erosion on the one hand and deposition on the other.

PROCESSES OF EROSION.

My purpose here is to make clear the erosive processes of each of the great erosive agencies, i. e., to show how each of the great erosive agencies through individual processes withdraws, removes, or get possession of materials from surfaces upon which they act.

Processes of Wind Erosion. The wind acts widely over the lands of the earth. In many regions no results of wind erosion may be noted because of the obscuring effect of other more important agencies. In certain areas, notably in dry or arid regions, the wind is an important agency in giving form and expression to the landscape. Perhaps the most outstanding form is that of the dune, a form of deposition, yet one implying erosion. Forms of erosion resulting from wind action are not always spectacular, nor are they as such always due to wind action alone. Wind erosion processes are less important as form producers than they are modifiers of existing forms. The individual processes are *deflation*, *corrasion*, and *attrition*.

Deflation is the process whereby wind removes loose materials from surfaces. This process is effectively presented by Grabau in his monumental treatise, "Principles of Stratigraphy," where he states that it is by far the most important work of the wind. Loose soils are often carried away; sands are picked up or moved along; and fine particles and dust are taken from the dry surfaces of the lands. Removal of the fine materials from certain dry desert areas, leaving a surface paved with coarse materials and rock fragments, is a fairly common thing, and such stony desert areas are known as the *Hamada* type. Loose sands may be taken from restricted localities forming "blowouts," some of which become the sites of intermittent lakes. Certain rock surfaces ex-

posed to the winds are kept clean of any loosened material formed upon them. Surfaces of certain mesa tops and other restricted upland rock surfaces in arid regions are particularly susceptible to this action of the wind. Cliffs of friable sandstone may be wind swept and occasionally alcoves or caverns may be hollowed out. Winds sweep certain sandy shores, continually removing the sands thrown up by the waves. Here deflation acts with little result in form production, as the sandy shore remains about the same regardless of much sand withdrawal. The great dunes, however, inland from the shore offer monumental testimony of the sand deflation which has taken place along the shore. Dunes themselves migrate by deflation, the loose sands being swept over and about the dunes where by deposition the dunes are reconstructed in the leeward direction. The great dust storms of the larger arid regions have their initiation in deflation. In humid regions much dust is moved about taken from dry surfaces, usually spectacularly when windstorms precede a rain following a dry spell.

Corrasion is the wear on surfaces by materials in transit in a wind or water medium, or the "tooling" effect of materials coming in contact with surfaces while being transported by wind or water. Sand grains are swept along by the wind and in passing over surfaces or coming against them these sands effectively cut them, detaching small pieces which themselves are swept along or taken bodily into the air by upward rising eddies. The pieces cut or knocked loose are subject to deflation and are removed from the place where they were loosened or detached. Grabau in his "Principles of Stratigraphy" calls attention to wind corraded rock surfaces in which furrows have been sculptured out. These sand-carved furrows separated by more or less fluted ridges are called "yardangs" in central Asia. Hard pebbles are polished and smoothed by the sand blown against them, and some of them are much faceted, having facets which meet at a sharp angle. These wind-faceted pebbles are known under the group name of "windkanter." The pebbles with two facets meeting in a single edge are known as "einkanter," and those with three edges are known as "dreikanter." Upstanding rock masses are beaten and worn by the wind-blown sands, and those sides or faces against which the wind comes are often irregularly or weirdly carved, the product of combined deflation, corrasion and weathering. Perhaps alcoves or caverns referred to above are in part due to corrasion.

Wind erosion is carried on also by *attrition*, or mutual wear of materials undergoing transportation. Sand grains are rounded by continuous bumping or knocking against each other or on other surfaces. The pieces detached from them are dust particles and these are bodily taken away by deflation. The sands of the desert are moved and removed, masses are shifted and reshifted, dunes are built and rebuilt, and as a result of this much wind-shoveling of the sands they are not only rounded by the wear, but are worn to dust, and, as such, are little by little taken out of the area entirely. Desert regions are no doubt lowered in this manner. Attrition is contributive to deflation, as indeed is wind corrasion.

Processes of Running Water Erosion. The most profound and widespread factor in land degradation is running water. Through precipitation great amounts of water are received by the land and much of it runs off over surfaces, gathers into streams, and passes out of the region where it fell. In passing over surfaces running water takes with it much earth debris, and where it flows in streams it carves out valleys and other landscape features. The erosive phase of the work of running water is that of taking material from the surfaces over which it passes and otherwise actively getting possession of the materials of the land. There are at least four individual ways in which running water actively withdraws or gets possession of materials at the expense of the surfaces with which it comes in contact. These are: (1) hydraulic action or "fluviraption," (2) corrasion, (3) attrition, and (4) corrosive attack.

Hydraulic action is the operating force of flowing waters. It is the moving power of flowing water which tends to take or takes with it such objects as are in its path or which it may encompass. As such, flowing water is a very important erosive and transporting agency. Any direct cleaning or washing action on surfaces by flowing water is hydraulic action. Loose material may be swept away by it. Rains wash surfaces clean, and off-flow of unconcentrated waters takes away much material from land surfaces. The unconcentrated waters gather much material and enter streams with it. Streams following rains are turbid with the material taken from the general surface which forms the gathering grounds for streams. Streams or sheets of water sweep up much material from stream beds, valley bottoms, slopes, and other surfaces during floods and heavy rains. The lifting action of swiftly moving streams is effective in sheety rocks, such as shales. The water is hydraulically driven under the sheets or slabs and they are directly lifted or turned over and moved downstream. Swift waters often draw out and hoist up materials which are structurally loose, such as much jointed rocks and friable sandstones. This hydraulic effect is sometimes referred to as "plucking," but the writer prefers to use this term as a distinct phase or process of glacial erosion.

It is here suggested that the term fluviraption³ be applied to this process of cleaning or washing surfaces, of seizing on to, lifting up, or moving along of loose material or material torn loose by the force of flowing water. Grabau⁴ has used the expression fluvial ablation for the same process. This process of fluviraption as described above is the most important process of fluvial erosion. Most materials carried in suspension by streams have been gathered from their basin surfaces by this cleaning process. Materials carried at and near the bottom of streams by traction have been taken from previous resting places by this process. Any material loosened or detached through corrasion is seized and taken

³ The term "fluviraption" is compounded from two Latin words, *fluvius*, moving, running or flowing water, and *raptare*, to tear away or to snatch up and carry away: hence *fluvi* and *raption* or *fluviraption*, the act of tearing away or snatching up and carrying away by flowing or running water. This term is interpreted to apply to the waters of both the land and the sea in their action upon surfaces. S. E. Stout, Professor of Latin, Indiana University, has approved the formation of this term as here used.

⁴ Principles of Stratigraphy, 1913, p. 17.

away by the same process. Attrition products formed in running water likewise are taken into the possession of running water by this process. Pothole drilling, waterfall excavation and sapping, and lateral quarrying and undermining by streams are striking localized phases of stream erosion. When analyzed these methods of stream erosion are seen to be the combined action of the single processes fluviraption and corrasion. It may be noted that fluviraption plays the same rôle in running water erosion that deflation does in wind erosion.

Corrasion has been defined above as the mechanical wearing of (rock) surfaces by rock waste in transit in a water or wind medium. Corrasion as thus defined has a rather limited meaning as an erosive process. As used in a number of texts the term is expanded to include any mechanical wear which rocks undergo in erosion, and as such includes attrition. Also it is used frequently in the sense of scour on surfaces, including in it the process defined above as fluviraption. Furthermore it is used to include the abrasion of rock which takes place in glacial erosion. I prefer to hold to the more restricted meaning of the term, as it then is applied to a specific process in erosion. If used in the inclusive sense which some authors ascribe to it, then it becomes equivalent in meaning to the term erosion and is useless.

Corrasion, as used in the narrow sense of its meaning, is not of great importance as a process of running water erosion. There is little corrasion on soil surfaces or the great gathering grounds of stream waters. It is largely confined to the beds of streams, but incidentally it acts on the banks or sides of stream channels. It is of little importance in stream beds which are in a graded condition or those which are composed of loose material. The principal process acting on such stream beds is fluviraption.

Corrasion is the "tooling" action of the materials in transit on or against surfaces which they strike. The "tooling" silt, sand or pebbles may have barely an instant of contact with the rock surfaces, acting in a striking or bumping manner, or the larger materials may more or less slowly rub or grind the surfaces over which they are moved, detaching particles which are immediately caught up by the transporting medium, victims of fluviraption. It is to be noted that corrasion as an effective process in erosion must have fluviraption or deflation act with it as a follow-up process. As noted above corrasion in conjunction with fluviraption is effective in detaching materials in pothole drilling, waterfall excavation and sapping, etc. Detachment of rock particles takes place through corrasion almost wholly when the rocks are firm and massive in character, for then fluviraption is of little avail as a single process. Scoured and smoothed rock surfaces in the rock-bound stream beds of certain youthful valleys are evidences of corrasive erosion.

Attrition is a process which is incidentally erosional in character. It is closely allied with corrasion and may not well be distinguished from it. The coarser materials undergoing transportation, or subject to transportation, at or near the bottom of a stream by the traction method, are comminuted by attrition. The fine particles detached from these materials are then subject to the suspension method of transportation.

Stones become rounded, as cobbles and pebbles, and sands lose their sharpness and also become rounded. Further wear reduces them and renders them more susceptible to transportation. It may be noted that the rounding of sand grains in water takes place much more slowly than rounding through attrition of sands under the action of the wind. In water the sand grains are somewhat protected by the film of moisture adhering to them, especially when the sand grains are smaller than seven-tenths of a millimeter in diameter. Also the water medium is more dense and the sand grains strike each other much less violently.

The term *corrosion* as used by most authors is a blanket term covering any and all chemical actions which alter or break down rocks at and near the surface. Running water passing over rock surfaces carries on more or less corrosive attack, chiefly through solution. Ordinarily solution and other corrosion processes are grouped under weathering, but, since running water is an actively moving agent, such work as it does in extracting material from surfaces may be classed as erosive in character. In its flowing action it sweeps away all products formed, allowing no residue or broken down products to accumulate, thus somewhat in contrast to the corrosion processes which act statically in the weathering processes. Here weathering and erosion are more or less arbitrarily separated. Corrosive attack by running water is probably of little quantitative importance.

Glacial Erosion Processes. Glaciers are masses of accumulated snow and ice which move out of a snowfield area into an adjoining area where they waste away. Glaciers in moving over surfaces or in coming in contact with them actively take material away, acting as an important erosive agency in the restricted areas of their occurrence. Glaciers are moving solids, hence their movement is very different from that of wind or water. They do not flow in the ordinary sense. While they actively acquire material at the expense of surfaces, transport it and deposit it, they do not do their work in the same ways as wind and running water, though the individual processes are somewhat comparable. It may be recognized that glaciers actively acquire material through the operation of four individual processes: viz., *exaration*, *plucking*, *abrasion*, and *gouging*.

Exaration is a term applied by Walther and Grabau⁵ to the action of glaciers in removing loose material from surfaces over which they move. The glacial ice gathers around or encompasses the loose material, holds it within its solid clasp, and moves away with it. In the region of snow and ice accumulation this process may keep all loose material cleaned from the surfaces over which this part of the glacier moves, but in the region of ice ablation the thinned and waning ice may not take up the loose material over which its lower portion is thrust; on the contrary, it may deposit some of the basal or other material which it has brought to or toward its terminus. Exaration as a process is comparable to deflation and fluviraption, wind and running water processes respectively.

Plucking is the process by which glacial ice withdraws rock frag-

⁵ Principles of Stratigraphy, 1913, pp. 17 and 263-264.

ments or blocks from surfaces by holding on to the upper surfaces or projecting parts. As a process it is particularly applicable to glacial erosion, though it is applied by some authors also to a phase of erosion by running water. It is an important process in the so-called "quarrying" action carried on by glaciers, particularly at the heads of valley glaciers. Surfaces from which rock fragments or blocks have been withdrawn by the plucking process of glacial erosion are very ragged and broken in appearance. Such surfaces because of their projecting rock masses are continuously favorable for further plucking. Plucked surfaces are especially noted in glaciated valleys about the cirque head and on the leeward or down-valley sides of roches moutonnées. Plucking as a process is regarded as independent of exaration, though in action the former may be regarded as a specialized phase of the latter.

Abrasion is the wear carried on by glaciers which move firmly held rock over other rock surfaces. Rock material frozen fast and incorporated in the basal portion of the moving ice sheet hundreds of feet thick, cuts effectively the rock surfaces over which the glacier moves. Both the rock imbedded in the base of the glacier, and that of the surface over which the rock-shod glacier moves, suffer through this abrasion process. It is the action of a moving solid held firmly and under pressure against another solid, and the rubbing or grinding of the one over the other constitutes abrasion. Both rock surfaces are effectively worn. Under this action rock surfaces are smoothed, striated and much worn away, and the tools by which this is done are faceted on one or more sides and likewise smoothed and striated. No other erosive process gives rise to such surfaces. The action gives to the glacier the "rock flour" which is incorporated through exaration into the body of the glacier, and which becomes a characteristic part of the debris that glaciers deposit or which characterizes the silt burden carried by streams escaping from glaciers. Abrasion may be regarded in its action as comprehending such attrition as is carried on in glacial erosion. As an erosion process glacial abrasion is quite different from corrasion as carried on by wind and water. Its products,—smoothed and striated surfaces, faceted and striated boulders and pebbles, etc.—are quite unique. It is a distinct process, and should not be regarded as equivalent to and interchangeable with corrasion, though it is a correlative phase of erosion.

Still another process by means of which surfaces may locally suffer in glacial sculpture is that of *gouging*. Glaciers are not readily mobile, and thus they are in contrast to air and water. They are solid, and as such they are likely in certain favorable places to be bodily pushed into soft rocks, such as clay shales, and actually plow up or shove forward masses of material which may be dragged or shoved along until over-ridden by the ice sheet. This is a sort of gouging process, and for want of a better term the writer has been describing it to students under the term "gouging" which is retained here. It is not likely that it is of any great importance in glacial sculpture.

Processes Involved in Wave and Current Erosion. Those waves and currents of lakes and oceans which come in contact with land at and

near shores are important agencies acting together to restrict and reduce the lands. The waves chiefly break up the rock masses against which they act and deliver the material to the currents which in their chief erosive function dispose of the wave eroded material. In many places along the coasts of the lands wave action is very spectacular in its attack on rocky shores. Currents, either associated with or independent of waves, without ostentation dispose of wave-given material. The actual processes involved in wave and current erosion are identical with those of running water on the land, but the manner of their exercise in most respects is quite different.

Certainly waves and currents carry on erosion by the process of fluviraption. Waves lave the rocks, cliffs and other features of the coasts often high above still water level. Forceful wave-sent waters are not only able to bring loose materials into the sea from the land, but, attacking in vulnerable places, are able to loosen and take possession of materials as well. The actual ways in which the washing attack (fluviraption) is carried on make wave erosion unique. Wave impact is a forceful broadside washing attack delivered by each wave that comes to the shore. In localities of spectacular wave action along the coasts the attack is undermining in character. Gravity favors material of the land being delivered to the sea. In wave attack water and air are driven with great force into cracks and crevices. These are the weakest places of the rocky land front which receives the attack. The hard-driven water and air in these places of weakness is followed by a release of the pressures between each successive wave. Any materials loosened are in time washed into the sea. Wave action also stirs up fine materials which had previously settled in shallow waters. Materials stirred up by the agitating waves go away with the masses of water which hold them in suspension, and ultimately these materials settle out of the water in places below wave-base or below the depth limits of wave action. Each storm with its complex of agitating waves and currents stirs up great amounts of fine material on the shallow platforms adjacent to the lands. A part of this material settles back upon the same platform, but much of it settles in deeper water. Removal of this fine material is one of the ways in which the platforms are lowered, allowing more efficient encroachment of the seas upon the lands. Fluviraption is also specifically carried on by currents, such as undertow, alongshore and tidal, in the removal of loose materials. Here the process behaves exactly as it does in running water erosion.

Corrasion is an important process carried on by waves and currents. One phase of it is the hurling of rocks, pebbles, etc., against cliffs. Such "artillery"⁶ action is very spectacular but rather uncommon. The wave-cut platform outward from the sea-cliffed shore line is commonly bare rock or has on it only a thin veneer of material. This has been called the "abrasion platform" by Johnson,⁷ chiefly because it is a field of intense wear. Waves and currents drive pebbles and sands over it, and these tools wear away the rock platform, but they themselves

⁶ Johnson, D. W., *Shore Processes and Shoreline Development*, 1919, p. 68.

⁷ *Shore Processes and Shoreline Development*, 1919, pp. 162 and 224-225.

suffer through attrition. Attrition and corrasion, individual processes of wear, are of great importance in wave and current erosion. The veneer of loose material is nearly always present on the platform, but this veneer is being constantly worn out through attrition, and the fine material and silt produced by the wear are taken by currents to the deeper and quieter waters where they settle out below wave-base. The veneer is constantly being replaced by wave eroded material which comes from the land. Corrosion may be dismissed as an auxiliary phase of marine attack doubtfully classed under erosion. It is incidental in wave and current erosion.

The combined processes of fluviraption, corrasion, and attrition, as carried on by waves and currents, act trenchantly on the lands where the sea comes in contact with them. The shore line where acted upon by these erosive processes retreats, and the platform seaward from the shore is deepened to the depth of wave-base and is greatly broadened as the shore line is eaten back. Truly the oceans consume the lands. Such is the view as regarded from the standpoint of wave and current erosion alone.

SUMMARY AND CONCLUSION.

In this paper an attempt is made to clearly present the erosive processes and to give the terms which to the writer appear suited to them. Attention is called to the confusion existing with respect to the meaning of a number of these commonly used sculptural terms, but little attempt is made here to cite the specific uses by various authors. Distinction is made between weathering and erosion, which are regarded as inclusive terms comprehending two sets of distinct processes which may act separately or in conjunction. Both sets together are comprised under the term denudation. This distinction is made on the basis of the uses of these terms by numerous authors who have described them or called attention to their results. It is a distinct departure from the organization (but not so much the use) of these terms as presented by Gilbert in Chapter V of his great classic, "Geology of the Henry Mountains."

The various individual processes of each of the great erosive agencies are described under the terms which appear to be well suited to them. Some eight individual processes in all are described as distinctive erosional processes; some are applied in the work of a single agency and some applied in two or more. Deflation is described as a process of removal of accumulated loose material from surfaces or removal of material at the time of loosening or availability by wind action. Its correlatives in the other erosive agencies are fluviraption and exaration; the first applied both to running water and to waves and currents, and the second to glaciers. Fluviraption is a term proposed in this paper for the name of the process in which the actively moving waters of either land or sea sweep away or seize onto and carry away loose materials or materials which may become loosened. Exaration is the term applied to the process of removal of loose material from surfaces by glaciers. Corrasion is used in the restricted sense of wear on rock sur-

faces carried on by materials in transit in a water or wind medium. It is of considerable importance in erosion by wind, and waves and currents, but of little importance as a single process in running water erosion. It has one correlative, that of abrasion in glacial erosion. Abrasion is a term applied to the process of the rubbing, cutting, or grinding action of one moving solid held firmly against another in glacial erosion. Attrition is the wear which tools in a water or wind medium undergo. It is regarded as an individual process taking place in erosion by wind, running water and waves and currents, very closely related to corrasion. Attrition is distinct from corrasion chiefly because material is not removed from stationary surfaces, but is a wearing out of the materials in transit or potentially in transit. It is an auxiliary process to deflation and fluviraption. Abrasion in glacial erosion comprehends it. Plucking and gouging are defined as special processes of removal in glacial erosion alone. Corrosion is a comprehensive term applied to chemical actions on rocks. It is a term of some significance in weathering, but has only a limited application as an erosive process as carried on by actively moving waters.

The processes described above are real. The terms applied to them are used specifically. Little that is new is brought out with respect to the processes or the terms applied to them. The writer has simply made an attempt to present a clarifying and organized view of the processes and the terms applied to them. It is not the hope of the writer to find his geological friends in full agreement with all the views set forth in this paper, but he does hope that they may see the need of a relatively specific meaning attached to the many common terms used in this paper.

ARCHEOLOGICAL INVESTIGATIONS IN GREENE COUNTY, INDIANA.

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One of the most interesting archeological areas in Indiana is located in the vicinity of Worthington, Greene County, Indiana. (Fig. 1.) It is at this point that Eel River joins the West Fork of White River and on the united flood plains of these rivers the town of Worthington is built. On the flood plain and on the higher lands forming the valley walls

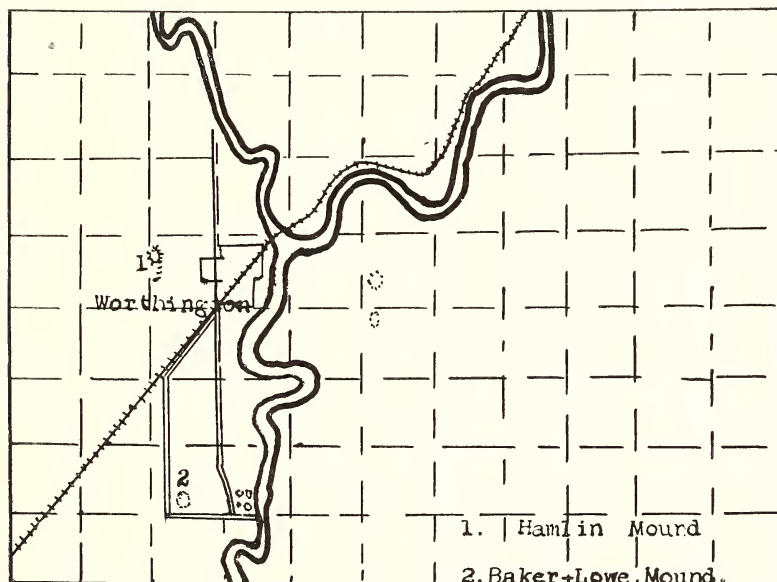


Fig. 1—Location of the Hamlin and Baker-Lowe mounds in Greene County, Indiana.

burials have been made in natural and artificial mounds. It is probable that some of the natural mounds of the flood plains were raised in order to bring them above the highest level of flood waters.

During the field season of 1926, and again in 1927, the members of the field party of the Division of Geology of the Indiana Department of Conservation spent some time in Greene County investigating mounds in the vicinity of Worthington. These investigations were undertaken at the request of Mr. Fred E. Dyer, a local collector of archeological materials, and a resident of Worthington. In 1926 the field party consisted of the writer and assistants J. S. Kaserman, A. E. Moore, J. E. Organ, and R. E. Stouder. Assistance was also given by Mr. Dyer and Carl Pottenger.

A small mound on the Dyer farm in Section 20, T 8 N, R 5 W was excavated. In the base of the occupied portion of this mound about four feet under the surface a rock floor was found. This floor was composed of slabs of sandstone of irregular shapes. These slabs were from three to four inches thick and from one to two and one-half feet in lateral extent. All of the sandy loam above the floor showed evidence of having been disturbed and contained fragments of bone, charcoal, and artifacts. The sand beneath the floor did not show any signs of having been disturbed.

The sandstones were probably obtained from outcrops of Pottsville sandstone which are present on the west bank of White River directly west of the mound. From the appearance of the surfaces of some of the sandstones it is apparent that fires had been built on the floor.

A field lying south of the Dyer mound contains a number of undulations of the sand dune type. Fragments of pottery, flint chips, arrow points, axes, charcoal, and bone fragments have been found on this surface.

The field party next excavated a mound rising some 20 feet or more above the general level of the White River flood plain in Section 1, T 8 N, R 5 W. This mound is a conspicuous feature and very symmetrical in outline but it contains no evidence of occupation, and such evidences were not to be found on the surface.

A group of small mounds, known locally as the "Circle Mounds," because of their circular distribution, were next examined. The mounds are grouped about a central depression. Some of them had had trees of large size growing upon them. These mounds are located north of the road which runs through the center of Section 4, T 7 N, R 5 W. No signs of occupation were found in any of these mounds. In the field to the south of the Circle Mounds are a series of undulations produced by sand movements. On the surface of these elevations flint chips and arrow points were collected.

Artifacts were collected from a cultivated field on the Hays farm near Point Commerce and several small mounds in this vicinity were investigated.

INVESTIGATIONS IN 1927.

The field party of 1927 consisted of the writer and assistants R. E. Esarey, Lewis Childs, S. T. Clashman, Geo. Whitlatch, H. Rankin, and J. S. Kaserman. Local assistants were Judge Oscar Bland, Fred E. Dyer, Carl Pottenger, and Thos. Bullock. Investigations began by the excavation of the Hamlin Mound in Section 19, T 8 N, R 5 W. This mound is situated on the rim of the valley wall which overlooks to the east the flood plain of the White River at its junction with Eel River. Near the point of juncture the city of Worthington occupies a portion of the flood plain. The mound is the most prominent topographic feature on a billowy surface but it does not rise very high above the general surface. Back of it toward the west is another elevation which is separated from the one excavated by a slight depression. Other mound-like elevations occur both north and south of the one excavated. The

slope of the rim toward the valley has been cultivated and on its surface fragments of pottery, arrow points, axes, and other objects have been found.

THE HAMLIN MOUND.

Stratigraphy. 4. The upper portion of the mound is composed of a sandy clay loam which has thickness of from nine to twelve inches. The amount of cementation in the layer gave evidence of the development of colloidal mineral matter.

3. Beneath the loam is a layer of dark sand or sandy loam which may represent an old soil. This stratum has a thickness of about two feet and contained the upper burials. It was less coherent and did not exhibit the degree of cementation of the upper layer.

2. The third layer from the top is a dark brown sandy loam containing some organic matter. It has a thickness of one to two feet and contained the lower burial zone which was from three to four feet below the surface of the mound. This layer was cemented and firm in places forming dense dark colored masses which may have represented burial spots of organic materials.

1. The lowermost layer of the mound consists of a light yellow sandy loam of the dune type in that general region. This layer showed no evidences of having been disturbed. No humus, charcoal or artifacts were found in it.

Size of Grain. In the sieve test of 2, 100 per cent of the sample passed the 40-mesh sieve; 63 per cent passed the 60-mesh sieve; 38 per cent passed the 80-mesh sieve; and 21 per cent passed the 100-mesh sieve.

Method of Excavation. In excavating the Hamlin Mound the following methods were used: An area 20 feet square was measured on the top of the mound. Excavation was begun along a line extending from east to west on the north side of the square, and also on a line extending along the east side of the square. From these two lines the work of excavation was carried forward toward the center of the square to the depth of the undisturbed layer of sand. The material below the top covering of loam was comparatively soft, unindurated, and easily removed by the use of spade and shovel except in certain spots where colloidal matter produced by organic materials had caused a certain degree of cementation. The top was first carefully removed and as soon as a burial was encountered the use of spade and shovel was abandoned and the object uncovered by the use of trowel, knife and brush. The finer materials immediately around the burials were sieved to recover small objects which might otherwise have escaped attention. In this way small objects such as beads were recovered.

Burials. The burials in the Hamlin Mound were in two horizons. The upper one was from one and one-half to two feet below the surface. The lower horizon was from three to four feet below the surface. The larger number of burials was in the lower horizon. There

was a very notable difference in the degree of decomposition of the materials in the two horizons. The materials of the upper zone were less decomposed and represented probably a much later time of burial. Some of the artifacts of the lower zone were more primitive than those of the upper zone. None of the burials contain evidences of anything but aboriginal occupation. In all burials where the lower limb bones were found in place the pedal extremities pointed in the general direction of the rising sun for that latitude in the later part of June. Some of the intrusive burials of the upper zone showed evidence of the bones having been bunched before burial.

Number 1. This burial was located near the northwest corner of the square and in the upper horizon. This burial contained a human skull, the bones of which were largely separated, and much decomposed. From impressions made in the sand by the skull it seems that the longitudinal diameter was about nine inches and the vertical diameter five inches. Near the skull was a badly broken pot with some of the parts missing. One notched and one unnotched arrow point were found near the skull. There were also some flint chips in the sands around the skull. (Fig. 2.)

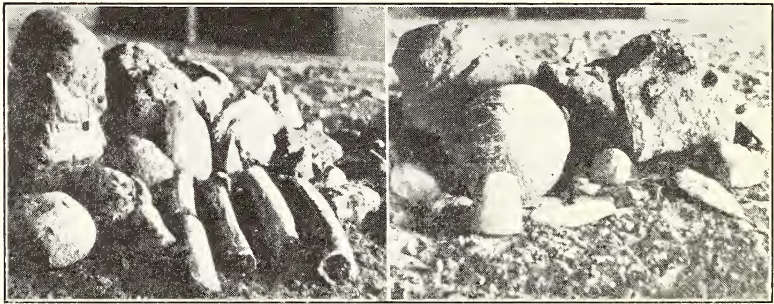


Fig. 2—From Hamlin Mound. At left, skull, pot, hammer, stone, celts, arrow points, and other bone fragments and artifacts from burial No. 1. At right, skull, other skeletal material, fragments of pottery, flint chips, and artifacts from burial No. 2.

Number 2. This burial was located about eight feet south of number 1. It contained the most complete skeleton of any of the burials. It occupied the lower horizon and the bones were very much disintegrated. The skeleton was in a supine position with feet pointing toward the northeast. Small sections only of the limb bones could be removed. The bones of the thorax were almost completely disintegrated but the imprint of the vertebrae was visible in the sandy loam. (Fig. 2.)

Number 3. Judge Bland and Mr. Dyer opened this burial on the east-west line of the square. Parts of four skeletons were found in the upper horizon. A pot, three skulls, and 34 arrow points were found.

Number 4. This burial was located near number 2 and contained a skull which has a vertical diameter of four and three-quarter inches, an anterior-posterior diameter of seven inches and a lateral diameter in the temporal region of five inches. The lower jaw has an anterior-

posterior length of three and one-half inches; distance between ramuses, three and one-fourth inches; height of ramuses two and one-fourth inches; distance from median line of jaw to posterior surface of last molar three and one-fourth inches; diameter of crown of largest molar seven-sixteenths inch; the maximum thickness of the jaw is three-fourths inch. This burial also contained other bone fragments, charcoal, and flints. (Fig. 3.)

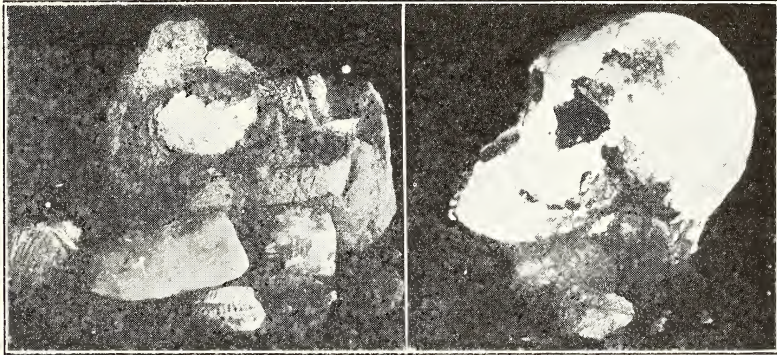


Fig. 3—From Hamlin Mound. At left, portion of infant's skull enclosed in pot which was in turn enclosed in a larger pot, fragments of pottery and flint, all from burial No. 6. At right, skull and flints from burial No. 4.

Number 5. This burial was located near number 3 in the north-east part of the square. It contained a skull, fragments of bones, charcoal, flint chips, arrow points, fragments of chert, and a pot which had a maximum lateral diameter of five and one-half inches and a vertical diameter of three and one-half inches. (Fig. 4.)

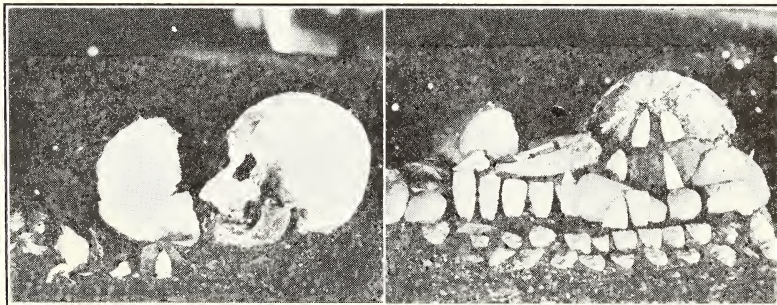


Fig. 4—From Hamlin Mound. At right, the bowl of a pot, fragments of the rim, skull, flint chips, charcoal and arrow points from burial No. 8. At left, fragments of a skull, other skeletal fragments, the bowl of a pot, 34 arrow points, 2 celts, a hammer stone and other artifacts from the Hamlin mound, burial No. 5.

Number 6. This burial was located near number 3. It contained a skull with lower jaw having 16 teeth, vertebrae, flints, and fragments of pottery. (Fig. 3.)

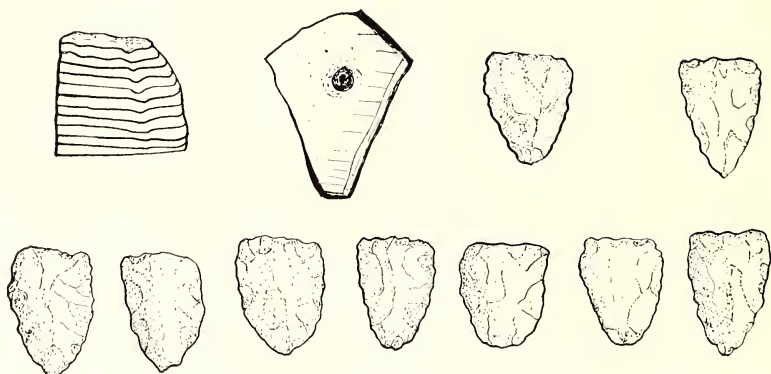


Fig. 5—Ripple marked sandstone, a sandstone pendant, and arrow points from the Hamlin Mound.

Number 7. This burial was located near the center of the square. A part of an infant's skull was enclosed in the basal portion of a small pot. The small pot was enclosed in the basal portion of a larger pot. The rims of both pots had been broken off. The skull seems to be that of a very young infant as there was little evidence of much ossification in the fragment which remained.

Number 8. Portions of a skull and fragments of other bones were found about five feet southwest of number 7. There were some fragments of pottery and charcoal in the burial. (Fig. 4.)

Number 9. A badly decomposed skull and fragments of other bones were found near the southwest corner of the square. These bones were in the lower horizon and badly decomposed.

Number 10. Small fragments of a badly decomposed skull were found near number 7. Fragments of bones, pottery, charcoal and flints were found at three other points in the square.

Figures 5, 6, and 7 show artifacts found in the Hamlin Mound.

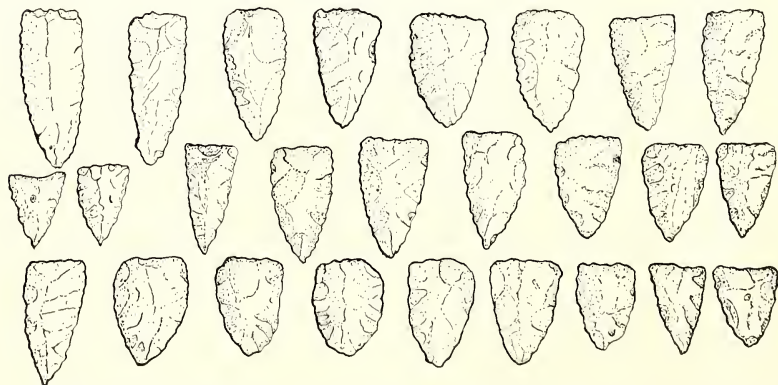


Fig. 6—Arrow points from the Hamlin Mound, all unnotched, a part of the collection covering one of the burials.

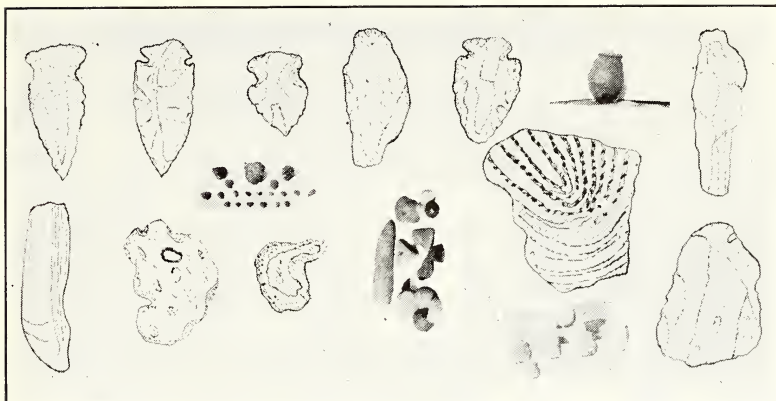


Fig. 7—A pot, pearl knife blade, axes, hammers, pestle, arrow points, and other artifacts from the Hamlin Mound and other mounds near Worthington.

BAKER-LOWE MOUND.

The Baker-Lowe Mound (fig. 8) is located on a former flood plain of the west fork of White River southwest of Worthington in Section 5, T 7 N, R 5 W. It is an elliptical mound having a length from east to west following the curvature of 249 feet and a width of 213 feet. The height of the mound above the general level on the west side is about 30 feet, and on the east side it is about 20 feet. The base of the mound covers about one acre of land. It forms a prominent topographic feature of the region and attracts the attention of passersby.

The upper part of the mound is composed of a sandy loess-like material. The light brown subsoil is covered with a darker brown soil. The body of the mound is composed of white sand which is probably water deposited although a part of it may have been wind-blown. The east slope of the mound is covered with about three and one-half feet of the brown subsoil and soil. The line of contact between the white sand and the overburden is somewhat irregular. At two points on the east slope the brown subsoil penetrated more deeply into the white sand than at other points. No burials extended below the line of contact or the upper surface of the white sand. The lower burials were a little above the line of contact and the upper ones within two feet of the surface.

Method of Excavation. Since permission was obtained by Mr. Dyer for only a limited examination of this mound it was decided to lay the mound off into four quadrants and to excavate the northeast quadrant. Starting at the base of the mound on the east side a ditch was dug to the central point at the top of the mound. In depth the ditch extended to the top of the white sand which exhibited no evidence of having been disturbed. Other ditches were advanced simultaneously. One from the north side to the top along the west side of the quadrant and two others at equal distances from the first two. Beginning on the

east the ditches were number 1, 2, 3, and 4 consecutively. On the lower slopes of the mound none of these ditches showed any evidence of occupation or disturbance. A stone hammer was found 40 feet from the top of the mound in ditch number 2. Bone fragments were found in this ditch about 30 feet from the central point. In ditch number 3, about 35 feet from the central point, a brown stiff clay loam containing bone fragments and shells was encountered. The brown layer dipped down into the white sand at this point and it was apparent that a burial had been made there. The larger part of the burials were found in that portion of the quadrant nearest the central point.



Fig. 8.—View of the Baker-Lowe Mound taken from the southwest.

Burials. (Fig. 9.) The surficial evidences of occupation have been abundant on the Baker-Lowe Mound. The fragments of bones, flint chips, pieces of pottery, and artifacts of various kinds have been picked up on its surface. The cultivation of land has aided in bringing these to the surface. A score or more years ago excavations were made and it is reported that three complete skeletons were removed from one point and that some perfect specimens of pottery were obtained along with other artifacts.

Number 1. The first burial was encountered in ditch No. 2 at a point about 40 feet from the central point at the top of the mound. At this point a hammer stone composed of an igneous rock of the diorite type was found. The hammer was probably carved from a glacial boulder. Yellow and gray flints, a black flint, and some fragments of a human skull were found nearby.

Number 2. This burial was encountered in ditch No. 1 about 23 feet from the center of the mound. It contained human skeletal material, the carapace of a terrapin, gastropod and plecy pod shells, marginella shell beads, bone beads, deer horn awl, a lime concretion, charcoal and flints. This burial was in the upper horizon.

Number 3. This burial was located in ditch No. 2 about 35 feet from the center. It contained fragments of human bones, charcoal, and flints. Apparently this burial had been disturbed at some time between

the last excavation and the time of burial as a dark soil was found in the material overlying the fragments mentioned.

Number 4. This burial was found about 13 feet from the center near ditch No. 1. The contents include human skeletal remains, animal remains, gastropod shells, a pearl knife blade made from the thick part of a plecypod shell, lime carbonate concretions, and some flint chips and artifacts.

Number 5. This burial was near ditch No. 1 about ten feet from the center. It contained human skeletal material, gastropod and plecypod shells and shell fragments, charcoal fragments, ripple-marked sandstone

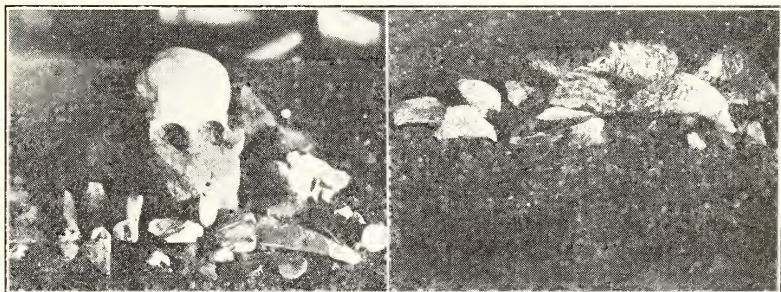


Fig. 9—From the Baker-Lowe Mound. At right, portion of an infant's skull, other skeletal materials, shells of gastropods, arrow points, pearl knife blade, fragments of pottery, beads, and other artifacts. At left, fragments of skull and pottery.

fragments, human teeth, a marginella shell bead, flint chips, and arrow points. This burial was in the upper horizon.

Number 6. This burial was found about ten feet from the center at a point about midway between ditch No. 2 and ditch No. 3. It contained a human skull, some small bones of the thorax, small fragments of larger bones, pottery fragments, flint chips and artifacts.

Number 7. This burial was located about 15 feet from the center midway between ditch No. 3 and ditch No. 4. It contained the anterior portion of the skull of an infant. The anterior-posterior length of the frontal bone along a median line is four and one-half inches, its width above the eye sockets is three and one-half inches. Other materials of the burial are bones of rodents, gastropod shells, fragments of pottery, human teeth with the roots absorbed, and flint chips and artifacts.

Number 8. This burial was located about 15 feet from the center midway between ditch No. 2 and ditch No. 3. This burial contained the skeletal remains of a small rodent, human bones, pottery fragments, and flint artifacts.

Number 9. This burial was located about 35 feet from the center near ditch No. 3. Human bone fragments were found, charcoal, flints, and shells were also found near the skeletal materials.

After excavating the northeast quadrant a ditch was dug along the line of ditch No. 1 across the top of the mound to the west. In the southwest quadrant a pit four feet square was dug 23 feet from the

central point and another one nearer the north-south line at a distance of 11 feet from the center of the mound. Another pit was dug about 20 feet from the center in the northwest quadrant in a line dividing the quadrant into two equal parts. No burials of importance were found in these pits. A few bone fragments were found in one and some charcoal and a human tooth in another.

The writer is indebted to Mr. Arch Addington and to Mr. R. E. Esarey for assistance in preparing the photographs used in this article.

A METHOD OF STUDYING THE FORM AND INTENSITY OF AN EXPLOSIVE SOUND WAVE.

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If a fine powder, such as lycopodium, is spread over a flat plate or contained in a glass tube and a sharp explosive sound allowed to set the air in motion, the dust will be left in fine striae, of a fairly constant pattern for any given conditions.

It is the purpose of this paper to call attention to two principles that seem to hold concerning these striae.

1. The striae represent the form of the air waves.
2. The distance between striae is a function of the intensity of the concussion.

1. Form of Waves. The apparatus used in studying these striae was a static machine arranged with leyden jars and spark gaps as shown in figure 1. The spark gap at S is the source of the sound waves studied, although a toy cap gun produced quite as good striae.

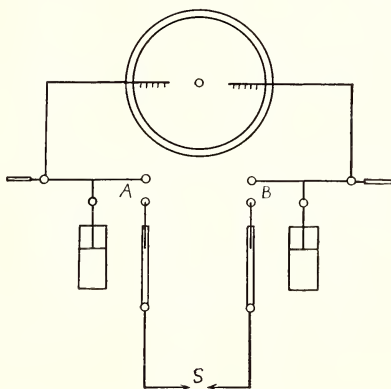


Fig. 1—Apparatus used in studying striae of air waves produced by explosions.

Figures 2 to 7 inclusive, which are explained in the legends, show convincingly that the striae mark the form of the sound waves and the above method of studying them is offered as a substitute for photographing sound waves when studying their form.

2. Intensity of Sound. A number of glass tubes all of the same size and containing lycopodium were placed radially about the spark gap at increasing distances from the gap. The average distance between striae was then measured for each tube and plotted against the reciprocal

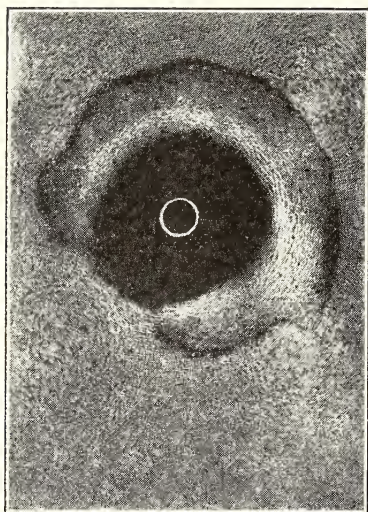


Fig. 2—Striae arranged in concentric circles about a spark which was passed through a hole in a glass plate covered with lycopodium.

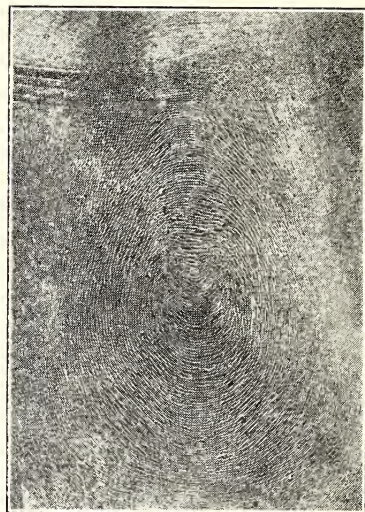


Fig. 3—Striae marking the image of a spark which was reflected from a cylindrical mirror made of tin.

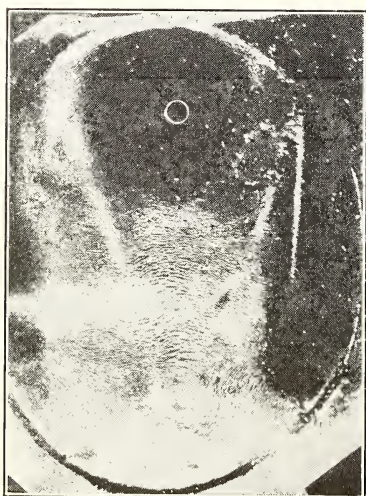


Fig. 4—Striae marking one focus of an elliptic mirror when the spark gap is at the other focus.

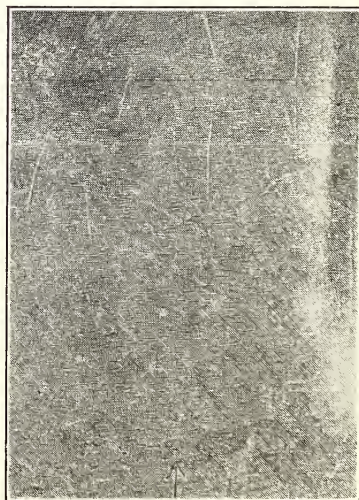


Fig. 5—Striae marking the plane wave form which has been reflected from a spark gap at the focus of a parabolic cylindrical mirror.

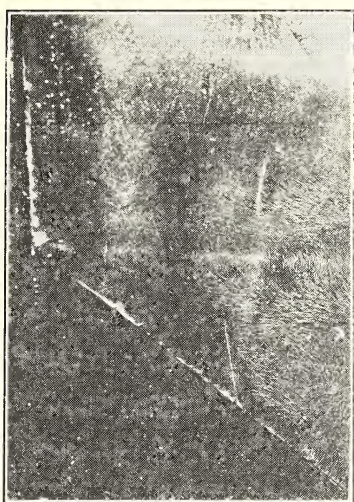


Fig. 6—A distinct interference band caused by a double reflection of the spark wave between two plane mirrors placed at an angle.

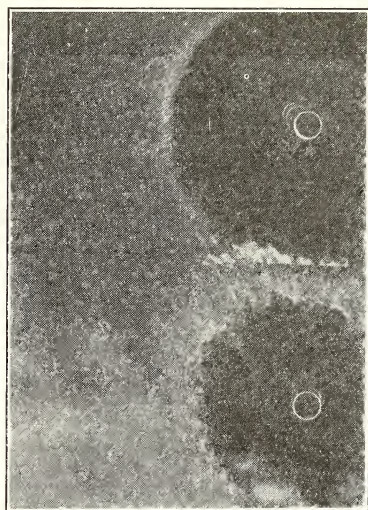


Fig. 7—Three interference bands caused by placing two spark gaps in series, one at each of the two holes in the glass plate.

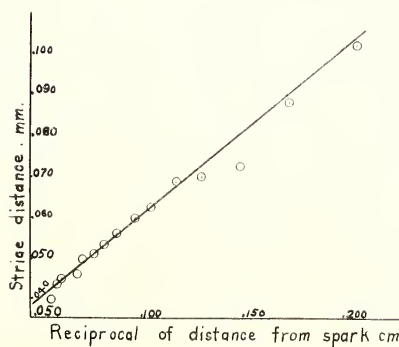


Fig. 8—Curve showing relation of width of striae to distance from source of sound wave.

of the distance of each tube away from the spark gap. The curve shown in figure 8 indicates that the striae distance is a linear function of the reciprocal of the distance from the source.

Since the intensity of sound varies inversely as the square of the distance from the source and directly as the square of the amplitude of the vibrating medium, these data show that the striae distance is a linear function of the amplitude of the vibrating air, a conclusion which seems reasonable after all, since it must be the to and fro movement of the air which causes them to form.

The above method is therefore suggested as a means of comparing sound intensities, as it can be worked within a few centimeters of the source.

As a practical application, two types of telephone mouthpieces, one the ordinary flared horn and the other of the parabolic type developed by Prof. A. L. Foley, were set up facing a spark gap. A powdered tube was placed at the diaphragm position of each horn. The striae were measured for each horn and the vibration amplitude ratios computed from the linear equation $Y = M X + P$. The amplitude ratio when squared gave the relative intensities of the sound collected by each type of horn. The resulting ratio of 1.3 in favor of the parabolic horn is exactly the same as obtained by Prof. J. E. Brock¹ by an electrical method.

My thanks are due to Prof. A. L. Foley who suggested the above problem and to the other members of the Indiana University Physics Staff and the graduate students for many helpful suggestions.

¹ Proc. Ind. Acad. Sci. 1922 (1923), p. 199.

SOME ATMOSPHERIC ELECTRIC POTENTIAL-GRADIENT MEASUREMENTS AT HIGH ALTITUDE.

J. F. MACKELL, Indiana State Normal School, Terre Haute.

Ever since the day of the famous kite experiment of Benjamin Franklin it has been known that electric phenomena associated with thunderstorms are identical with other electric phenomena associated with batteries, dynamos, etc. Since that time a great amount of research has been carried out in the field of Atmospheric Electricity.

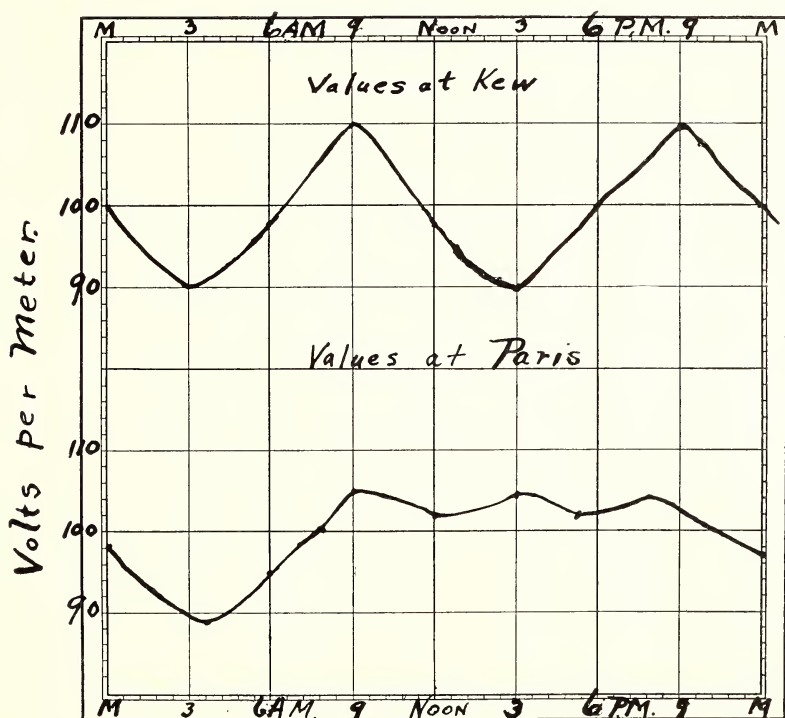


Fig. 1.—Curves showing diurnal variations of the potential-gradient at Kew and Paris.

Since the latter part of the last century rather elaborate experiments have been attempted in an effort to associate the earth's residual magnetism and electric potential with electric potentials and charges in the atmosphere. In England, France, Germany and the United States land and sea with the result that we now have a rather complete set of expeditions such as that of "The Carnegie" have been carried out over

experimental data dealing with this subject. The publications of J. H. R. Wilson, G. C. Simpson, L. A. Bauer, R. E. Watson and W. F. G. Swann have been devoted very largely to phenomena of this nature.

As a result of these experiments and others it is a well-known fact that at different points on the surface of the earth, different potentials exist simultaneously. These differences of potential are not usually of a high order of magnitude but when one takes readings of the potential at points in the atmosphere it is found that a vertical gradient exists which is of the order of 100 volts per meter at points near the earth. This potential-gradient becomes smaller as one ascends and finally becomes negligible at an altitude of a few miles above the surface of the earth.

It has been found that the values for the potential-gradient at such places as Kew Observatory, where a record covering many years has been kept, passes through a cycle of diurnal and annual variations. In general the values are higher in winter than in summer and the potential is of a positive sign. At Kew Observatory the diurnal curve shows maximum points at about 9 AM and 9 PM with well-defined minimum points at about 3 AM and 3 PM. The diurnal curve for values at the Eiffel Tower are similar for night values but vastly different for day values as is shown graphically in figure 1.

Curves showing values for other stations over the earth show variations of a great number. Most of them, however, bear similarities to one or the other of the two curves illustrated. As can be seen, the great difference in these two curves lies in the fact that in the Kew curve there is but one daytime maximum and one daytime minimum, whereas on the Paris curve there are two of each.

Most of the published data concerning the potential gradient are concerned with values near sea level, and in our own Rocky Mountain region very little work has been done along this line. During the summer of 1927 the writer availed himself of the opportunity afforded him by the generosity of the Physics Department at the University of Colorado to make some observations there. The elevation at Boulder is 5,380 feet and the climate there during the summer is especially well adapted to such work.

The recording apparatus used consisted of an Alpha Ray gold leaf electroscope which was redesigned for the purpose and which was extremely sensitive, having a capacity of only one centimeter. In order to determine the potential at a point in the air a brass rod, so designed that its length might be varied at will, was extended out of a window on the third floor of Hale Science Building. On the end of this pointed rod, a collector consisting of a glass bottle, which at one time contained radium, was fastened. This collector was very potent in ionizing the air near the point of the rod and thus the rod came to the potential of the point in the atmosphere in a very short time. Obviously the rod and conducting system were thoroughly insulated, and the case of the electroscope was earthed to a water pipe.

Observations were taken daily over a period of five weeks. These readings were taken at five-minute intervals in the main. Most of the observations were made between the hours of 6 AM and 8 PM. All

points on the curves shown represent from twenty to forty observations. The three curves of figure 2 show the results for clear days, cloudy days and all days taken together.

The values represented by the curves for the potential-gradient at Boulder are absolute values. It has been pointed out by Chree¹ that the equipotential surfaces for regions in the vicinity of a long wall or the long side of a narrow building are such that at a point near the wall

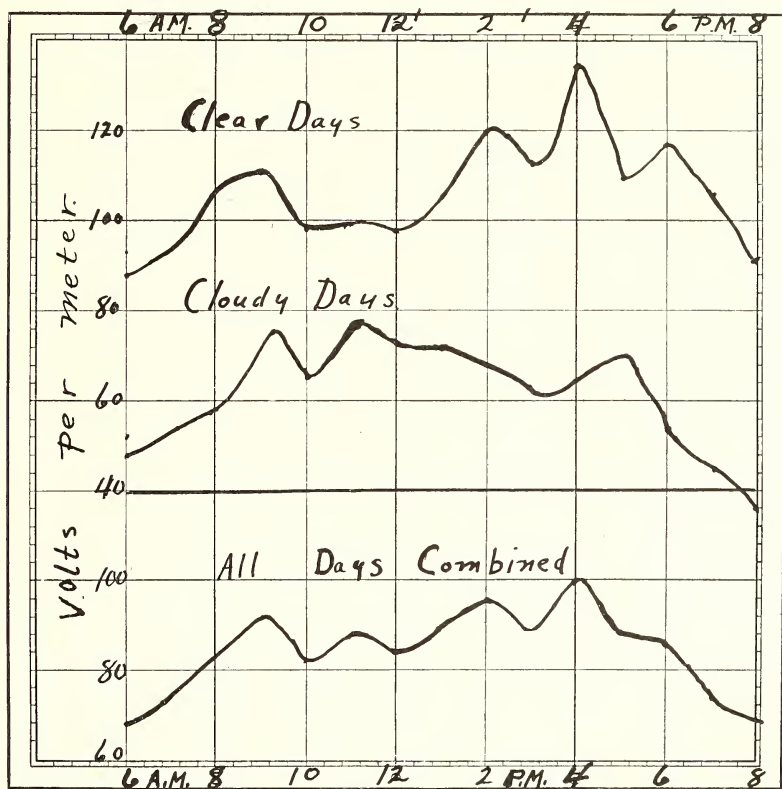


Fig. 2—Potential gradient curves for Boulder, Colorado, July-August, 1927. Diurnal variations.

and at a height .808, the total height of the wall, the values for the horizontal gradient may be substituted for the absolute vertical gradient values at points near the earth's surface and remote from the wall. Thus it was merely necessary to choose a window at approximately this height and keep a record of the distance of the pointed collector from the wall of the building. This distance was kept at three meters for most measurements.

As might be expected, the curves show a decidedly higher set of values for clear days than for cloudy days. The 9 AM maximum point

¹ Proc. Royal Society, vol. 91, p. 440.

shown in both the Paris and Kew curves is evident in the curves for Boulder. The early morning and late evening minimum points are also clearly shown, but as regards the values for the middle of the day the Boulder curves show no similarity to the Kew curve. The curve for clear days shows a very high maximum for mid-afternoon as does the Paris curve. The order of magnitude of the potential-gradient was about the same as those for Kew and Paris on clear days at the same

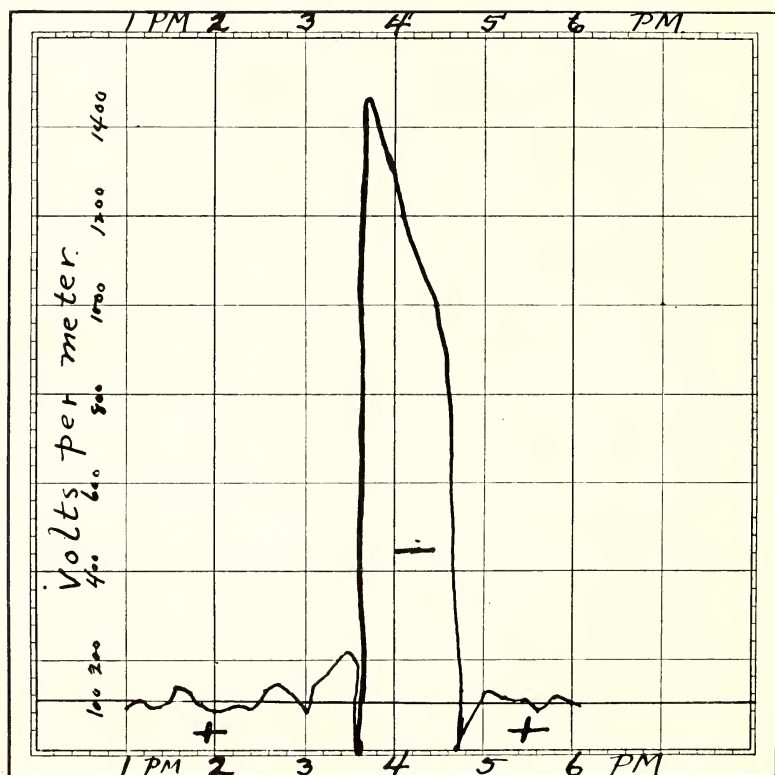


Fig. 3—Variations of the potential-gradient at Boulder, Colorado, during a thunderstorm, August 22, 1927.

period of the year. When all days are considered, however, as is the case at Kew and Paris, the mean values are about ten per cent lower than those at the above named places. The greater ionizing effect of the sun at higher altitudes will account for this, but the effect of the altitude is not as great as might be inferred.

While these readings were being taken an effort was made on three or four occasions to obtain values during a thunderstorm. In one case the effort was attended with remarkable success. The curve shown in figure 3 shows the record for the afternoon of August 22. At one o'clock the sky was absolutely clear and so remained until about 3 PM, when

clouds began to appear from the mountains. The potential-gradient, which was of a positive sign, began to rise until about 3:30, when it suddenly dropped to zero at 3:35. Lightning was beginning to flash at intervals but no rain was falling as yet. At this point the potential-gradient changed sign to negative and rose rapidly until 3.47, when it had risen to 1,440 volts per meter. It dropped quite suddenly as the cloud passed and reached zero again at 4:45. Here it again changed sign to positive and rose to normal values. The sky had now cleared perfectly, as is the usual case in mountain storms. During the storm a few drops of water fell but the disturbance was of a very mild character.

This curve shows clearly what generally takes place when a thunder storm passes over. The potential of the atmosphere usually changes sign, as does the earth at this point, and the order of magnitude of the gradient becomes exceedingly high. Quantitative values are very difficult to obtain, however, and very few have been published.

In conclusion it occurs to the writer that since we are concerned nowadays so much with radio transmission and reception, a study of atmospheric electricity, especially with reference to the potential-gradient, might be of much use. It might be added furthermore that recent values for the potential-gradient at Kew show a decided tendency to become much greater since the war and this is attributed by Chree and Watson² to atmospheric pollution due to smoke from factories which have sprung up in the vicinity. Some correlation between smoke pollution of the atmosphere and the prevalence of destructive thunderstorms might be shown.

The writer wishes to acknowledge his indebtedness to Professors O. E. Lester, J. W. Broxon and W. B. Pietenpol of the Physics Department of the University of Colorado for their gracious assistance in furnishing the apparatus and for their kindly suggestions during the course of the research.

² Proc. Royal Soc. vol. 105—1924, pp. 311-333.

INDUCTION AND RADIATION.

R. R. RAMSEY, Indiana University

The equation $H = \frac{I ds}{r^2} \cos \theta$, where H is the magnetic field at P , (fig. 1)

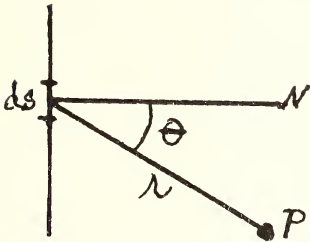


Fig. 1—Illustrating a portion of a straight wire in which a current, I , is flowing. The field, H , at the point, P , is $H = I(ds/r^2) \cos \theta$. When the point, P is a great distance from the wire and perpendicular to the wire, $H = Ih/d^2$. The vector potential is $A = Ih/d$.

$I ds$ is an element of current length ds , r , is the distance of the point, P , from the element $I ds$, and θ is the angle between the line joining P and ds and the normal to ds , may be said to be the fundamental equation giving the relation of current strength to the magnetic field about the current. From this equation we get our definition of unit current. In speaking of this equation we shall consider the point, P , to be on the normal to ds , and the angle

$$\theta = 0, \text{ so that } H = \frac{I ds}{r^2}$$

is the form of the equation. If we apply

this equation to a current flowing in a circular wire (fig. 2) we have I times length divided by r^2 , or $H = 2\pi I/r^2$ or $H = 2\pi I/r$ for the value of H at the center of the circle.

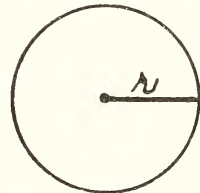


Fig. 2—When the equation $H = I(ds/r^2) \cos \theta$ is applied to a circular coil carrying a current the field, $H = 2\pi I/r$, at the center of the coil.

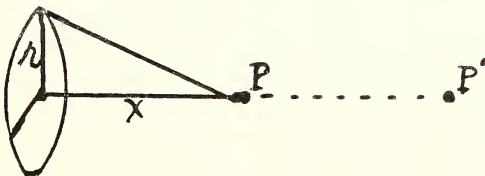


Fig. 3—When the field is calculated for a point on the normal to the coil, $H = 2\pi r^2 I/x^3$ if the distance, x , is great compared to the radius of the coil. Or $H = 2IA/x^3$.

If P (fig. 3) is on the line which is perpendicular to the circle at the center and at a distance x from the center, then we have $H = 2\pi r [I/(r^2 + x^2)] (r/\sqrt{r^2 + x^2})^{\frac{3}{2}}$ or $H = 2\pi r^2 I/(r^2 + x^2)^{\frac{3}{2}}$. When the distance is great, as at P' , then $H = 2\pi r^2 I/x^3 = 2IA/x^3$.

When the current is flowing in a straight wire of infinite length then $H = 2 I/r$. If the current is flowing in a wire of finite length, which is short compared to the distance x , then $H = I h/x^2$ where h is the length of the wire.

If we consider a circuit which carries a current to be equivalent to a magnetic shell (Starling, p. 225), we have for the potential at a distant point P, on the normal to the circuit (fig. 3) $V = IA/x^2 = I\omega$, where ω is the solid angle at P' subtended by the circuit. If the current has the same effect as the magnetic shell, then the potential at P' is $V = M/d^2$ where M is the magnetic moment of the magnetic shell and d is the distance of P' from the magnetic shell. d is the distance from the north face of the shell, or d centimeters from the center of the magnet "end on". If we solve for the potential at a point in the plane of the circuit which is the plane of the magnetic shell, (fig. 4) we get $V = I\omega = 0$. This is the same as the potential at a distance d from a short magnet "broad side on". (Starling, p. 13). If we differentiate the first equation with respect to the distance or with respect to x, we have

$$H = \frac{-dV}{dx} = \frac{-d\left(\frac{M}{x^2}\right)}{dx} = \frac{2M}{x^3} = \frac{2I\omega}{x} = \frac{2IA}{x^3}$$
 which is the same as was derived above.

When the point is in the plane of the coil the potential is zero but the field H is not zero. The field is the derivative of the potential with respect to the direction at right angles to the distance d. At a point near the plane of the coil (fig. 4) we have $V = I\omega = IA \sin \theta/y^2 = (IA/y^2) x/y$. $H = -dV/dx = -IA/y^3$. The field in the plane of the coil is one-half that along the axis of the coil when the distance is the same in both cases.

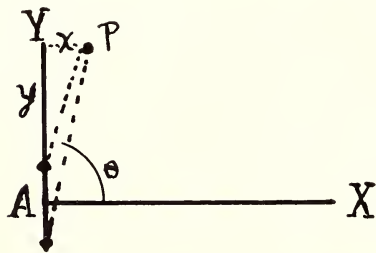


Fig. 4—When the point P, is in the plane of the coil the field is IA/y^3 , y, being the distance of P, from the coil. The potential is zero but the field is the space derivative of the potential which gives $H = IA/y^3$.

The value of the field H is the field due to a current, I. This current, I, is assumed to be direct current. If it is alternating current we assume that the virtual field "root mean square" field produced by the virtual current, I, is the same as that produced by the direct current of the same numerical value. It is this field which is called induction. Thus induction is the field we usually think of when we speak of self-induction, of mutual induction, of transformers, and of induced currents.

Due to induction, energy is stored in the field when current is increasing and is again absorbed into the circuit when the current is decreasing. In a pure inductive circuit with alternating current no energy is dissipated. The current is "wattless".

If, as is sometimes done, we try to explain the action of an aerial by assuming a perpendicular wire with a capacity such as a large ball at the top, we can picture the magnetic field as circles about the wire and the electric field as lines which start from the ball and curve downwards until they end on the ground, we get a picture (fig. 5) which answers the purpose until we try to explain the fact that the magnetic and electric fields are in phase as is shown from Maxwell's equations. The fields about the aerial as we have pictured them are out of phase. The magnetic field is a maximum when the

current is a maximum and the electric field is a maximum when the charge on the ball is a maximum, which is at a time when the current is zero and the magnetic field is zero. This is due to the fact that in the picture we have been

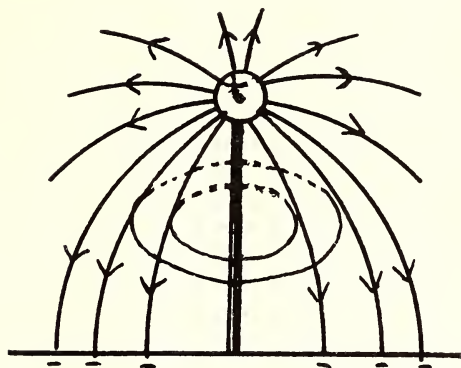


Fig. 5—An elementary picture of the fields about a vertical antenna. The magnetic field is represented by the circles about the antenna and the "spray" lines represent the electric field. Our ordinary conception of magnetic field, which is induction, has led many text books to give wrong statements.

thinking of the field called induction and in the Maxwell equations we are dealing with the field called radiation.

To get the radiation we make use of the vector potential. The line integral of the vector potential is equal to the surface integral of the magnetic flux. To illustrate a line integral we will take the line integral of the electromotive force which is equal to the surface integral of the change of flux. The line integral is equal to the work done in carrying a unit quantity around the path. Suppose we have a wire bent into a rectangular loop of a single turn. Now potential difference is equal to the work required

to move a unit from one point to another point. The e.m.f. in the loop is the work required to move a unit quantity of electricity around the loop, or e.m.f. is the line integral around the loop. Since $E = -dN/dt$ the e.m.f., E is equal to the rate of change of flux through the coil. The total change of flux through the coil is equal to the surface integral of $\mu dH/dt$ taken over the surface area of the coil. In the wire if it is a closed loop there will be an induced current flowing in the wire. The rectangle does not need be a conductor. The rectangular circuit

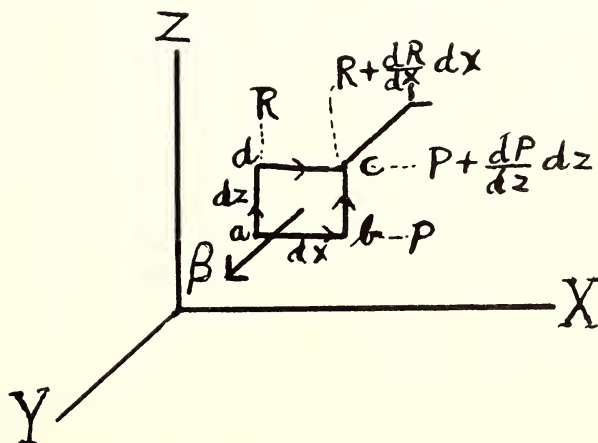


Fig. 6—The work done by carrying a unit charge of electricity around the rectangular p equal to the potential induced by the change of the magnetic field, β , through the co

might be made of a glass tube. The line integral may be thought of as being the work done by pulling a unit charge through the tube by means of a "greased" thread which had been threaded through the tube. The e.m.f. will be equal to the rate of change of flux the same as if a conducting wire were there. The rectangle may be an imaginary rectangle or path in space and the flux may not be perpendicular to the face of the imaginary circuit, and the statement that the line integral of the e.m.f. is equal to the surface integral of the charge of magnetic flux still holds.

Imagine a rectangular path in the X Z plane whose area is $dx dz$ (Fig. 6). Let the magnetic field, H , have the components α , β , γ , in the x , y , and z directions respectively. Let the electric field, E , have components P , Q , R . Let the path be represented by the square $a b c d$ in the figure. Then the rate of

change of magnetic flux through the area will be $\mu \frac{d\beta}{dt}$ and the total change of

flux will be $\mu \frac{d\beta}{dt} dx dz$. Let the component of E along the line ab be P . Then

the component of E along the line dc will be that along ab plus the change in moving a distance dz in the Z direction. This change is equal to the space

rate of change, $\frac{dP}{dz}$, times the distance. Then the value of E along dc will

be $P + (dP/dz)dz$.

The component of E along ad is R , and that along bc is $R + (dR/dx)dx$. Then the work done in taking our unit quantity along the path $abcd$ is $Pdx - [R + (dR/dx)dx] dz + [P + (dP/dz)dz] dx - R dz$ which when added and simplified is $(dP/dz - dR/dx)dx dz$. Since $E = -dN/dt$ this is equal to

the negative of the rate of change of flux, which is $-\mu \frac{d\beta}{dt} dx dz$, or $-\mu \frac{d\beta}{dt} dx dz$

$= (dP/dz - dR/dx) dx dz$. $dx dz$ can be cancelled out. Going through similar operations in the other two planes we get the two similar equations.

The three equations are:

$$-\mu \frac{d\alpha}{dt} = \frac{dR}{dy} - \frac{dQ}{dz}$$

$$-\mu \frac{d\beta}{dt} = \frac{dP}{dz} - \frac{dR}{dx}$$

$$-\mu \frac{d\gamma}{dt} = \frac{dQ}{dx} - \frac{dP}{dy}$$

The shorthand method of writing these equations is $-\mu \frac{dH}{dt} = \text{Curl of } E$.

Now for the line integral of a vector potential. Let A be the vector potential with components $A_x A_y A_z$. So far we have not said what A is. If the line integral of A is equal to the surface integral of the magnetic field we can from the analogy of the line integral of the e.m.f. write the equation in "shorthand",

$H = \text{Curl of } A$, or writing in full

$$\alpha = \frac{dA_z}{dy} - \frac{dA_y}{dz}$$

$$\beta = \frac{dA_x}{dz} - \frac{dA_z}{dx}$$

$$\gamma = \frac{dA_y}{dx} - \frac{dA_x}{dy}$$

If the magnetic field at P (fig. 7) is due to current in the vertical aerial at the origin, then $\alpha = 0$, $\gamma = 0$, and β , the component parallel to the Y axis, is the only component.

$$\text{Then } \beta = \frac{dA_x}{dz} - \frac{dA_z}{dx}.$$

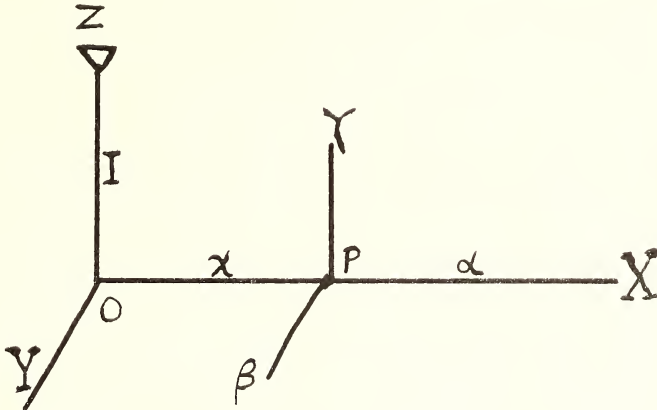


Fig. 7—The magnetic field, radiation, at P due to alternating current in a distant aerial, OZ, is the Y component, β . β is in phase with the electric field which is parallel to the antenna OZ. The two fields are in time, phase; in space quadrature.

A must in some manner depend on the current in the aerial and since this is a long vertical current A will not change as we move up in the Z direction

above P. Then $\frac{dA_x}{dz} = 0$.

$$\text{Then } \beta = H = -\frac{dA_z}{dx}$$

From the above we have $dA_z = -Hdx$ $A = -\int Hdx$.

But we have assumed for constant current that $H = \frac{Ids}{r^2} = \frac{Ih}{x^2}$ where h is the height of the aerial $x = r$ the distance between P and the aerial.

$$\text{Then } A_z = -Ih \int \frac{dx}{x^2} = \frac{Ih}{x}.$$

$$\text{From this we have } H = \frac{dA}{dx} = \frac{d\left(\frac{Ih}{x}\right)}{dx}.$$

Of course, if we take the derivative we will get our old value for H , but we have heretofore assumed that the current in the aerial is direct current or the equivalent to direct current. This is not true. The current is alternating current, or $I = I_0 \sin \omega t$. Also, it takes some time for the field to reach the point, P . The field at P is due to the current which was in the aerial a fraction of a second before the time t .

Then $I = I_0 \sin \omega(t-t')$. Since space equals velocity times time, $t' = x/v$ where v is the velocity of light, then the current is $I = I_0 \sin \omega(t-x/v)$

$$\text{and} \quad H = \frac{-d}{dx} \left(\frac{h I_0 \sin \omega(t - x/v)}{x} \right)$$

differentiating,

$$H = +\frac{hI_0}{x^2} \sin \omega(t - \frac{x}{v}) + \frac{hI_0\omega}{vx} \cos \omega(t - \frac{x}{v}) .$$

Thus we see that the field, H , consists of two parts. The first is the field we get by considering the current to be constant, or if alternating current, by considering the field to be independent of the sine of the angle. This virtual field is numerically the same as the field due to a D.C. current.

The second part is that in which we consider the angle to depend on the distance x . The two parts are out of phase by 90 degrees. We remember we had trouble with the ordinary field in our elementary picture because it was out of phase with the electric field. This second part is in phase with the electric field.

The first part is induction. The second part is radiation. The first part the induction diminishes as the square of the distance while the second, the radiation, diminishes as the distance.

We can write the virtual values of the magnetic field by considering the sine and cosine to be unity, and writing I for the virtual current, then

$$\text{Induction, } H = hI/x^2$$

$$\text{Radiation, } H = hI\omega/vx.$$

If I is measured in amperes, $I/10$ will give the value of I to make the field in lines per square centimeters.

$$\text{Since} \quad \frac{\omega}{v} = \frac{2\pi}{\lambda}$$

$$\text{Radiation, } H = \frac{hI \, 2\pi}{10\lambda x} .$$

Equating the two values and solving for x we find that the two components of H are numerically equal when $x = \lambda/2\pi$. At a distance equal to $1/6.28$ of a wave length the two values are numerically equal. Since they are in time quadrature the measured value will be 1.414 times the calculated value of one. Closer to the aerial the value of H is nearly all induction and diminishes as the square of the distance. Beyond this point the field is mostly all radiation and varies inversely as the distance.

For practical purposes when the distance is less than $1/20$ of a wave length the radiation can be neglected, and when the distance is greater than $1/2$ wave length the induction can be neglected.

If instead of an antenna aerial we have a coil aerial the induction can be calculated as is done in the first part of the paper. Induction is the ordinary

field due to direct current. It is found to diminish as the cube of the distance from a coil. It is $21A/d^3$ perpendicular to the plane of the coil and IA/d^3 in the plane of the coil.

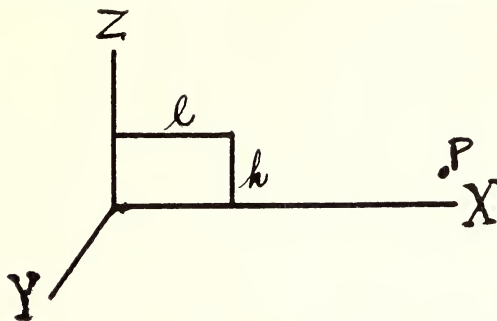


Fig. 8—A square coil carrying radio frequency current produces two fields at the point, P. The induction diminishes as the cube of the distance while the radiation diminishes as the first power of the distance.

the vector difference of the two equal vectors which differ in direction by a small angle, $\theta/2\pi = 1/\lambda$ or $\theta = 2\pi/\lambda$. In the diagram (fig. 9) $oa = 2H_1 \sin \theta/2$. Since θ is small, $\sin \theta/2 = \theta/2$, then

$$oa = H = 2 \left(\frac{hI\omega}{vx} \right) \frac{2\pi h}{2} = 4\pi^2 h n I / 10 \lambda^2 d.$$

Thus the radiation from a coil varies inversely as the distance while the induction varies inversely as the cube of the distance.

The radiation from a coil varies inversely as the square of the wave length while from an antenna aerial inversely as the wave length.

The induction from a coil is IA/d^3 and the radiation from the same coil is $4\pi^2 IA/\lambda^2 d$. Equating the two values

we get $\frac{1}{d^2} = 4\pi^2/\lambda^2$ or $d = \lambda/2\pi$. Thus the two components

are equal at a distance $\lambda/6.28$, the same being true for an antenna aerial. Figure 10 gives the relative distribution of radiation and induction about a coil at a distance, $d = \lambda/2\pi$. Close to the coil or antenna aerial the field is primarily induction. Figure 11 gives the distribution when $d = \lambda/20$. The energy represented by induction does not leave the aerial. It is stored in the medium during the first fourth of a cycle and then returns to the aerial during the second

Fig. 9—The two vertical sides of length, h of the square coil produces two equal radiation fields but due the distance, 1 , they are slightly out of phase. The vector difference is proportional to the vector oa .

fourth of the cycle in the same manner as the field of an ordinary transformer or choke coil. The induction is the field which stays at home. The energy of the field of the radiation does not return to the aerial but passes out to infinity unless it is absorbed by intervening objects. The energy is radiated into space.

Of course it is possible to absorb a part of the energy of induction if the absorber is in the field of the induction, that is, near the aerial. This is the same

as in a transformer; part of the energy may be absorbed by the secondary coil, in which case it can not return to the primary.

It will be noted that radiation from a given aerial depends upon the frequency or wave length. Induction is independent of frequency. The virtual value of induction field for 60 cycle, 300 meters or 41 meters is numerically the same as that produced by D.C. current.

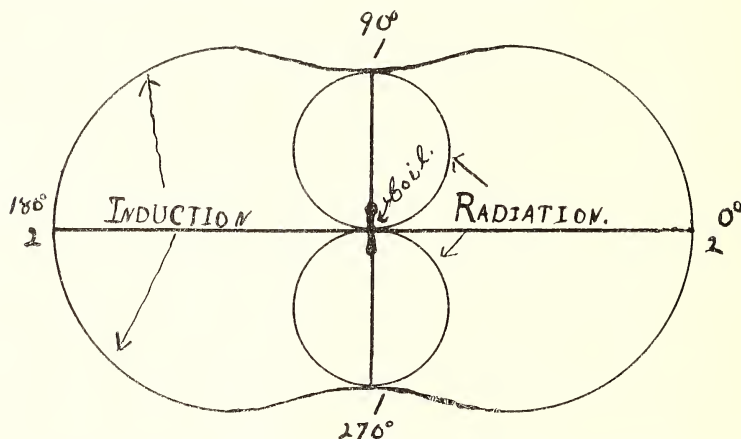


Fig. 10—In the plane of a coil the radiation field and the induction fields are numerically equal when the distance from the coil is equal to the wave length divided by 6.2832. The figure shows the relative values in all directions about the coil. Perpendicular to the coil radiation is zero and induction is two times that in the plane of the coil.

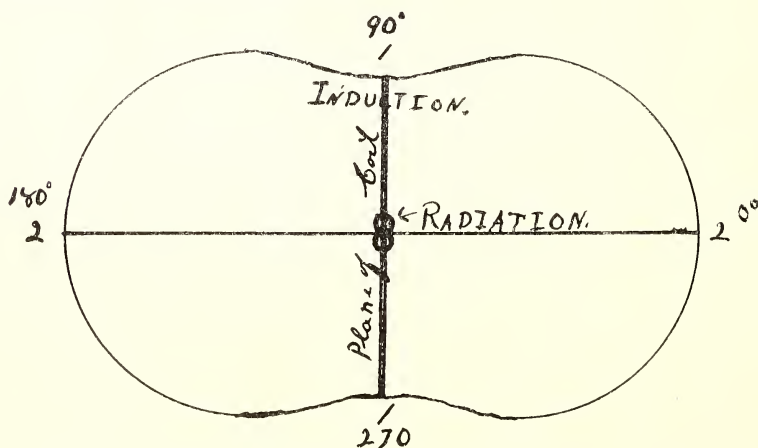


Fig. 11—Shows the relative values of the two fields when the distance is one twentieth of a wave length. The induction is many times the radiation.

We have spoken of the magnetic field only. Maxwell's equations show that the energy of the magnetic field is exactly equal to the energy of the electric field. Thus if we know the magnetic field we know the electric field. The electric field and magnetic fields are always associated together. They

are two aspects of the same thing. They really are the same thing in a certain sense. For an illustration take a simple D.C. circuit. The current through a coil is equal to the total e.m.f. divided by the total resistance. The current is also equal to the P.d. at the terminals of the coil divided by the resistance of the coil. These two values are equal. The current in the coil is not $2I$. In the electro-magnetic system of units the ratio between E and H is 3×10^{10} . E in absolute units of potential per centimeter is equal to H in Gilberts times v , (3×10^{10}).

$$E = Hv = 3 \times 10^{10} H.$$

If we divide by 10^8 we have E in volts per centimeter. Multiply this by 100 and we have E in volts per meter. If we reduce this to micro-volts by multiplying by 10^6 we again have

$E = 3 \times 10^{10} H$ micro-volts per meter; thus $H \times v$ is either absolute units of potential per centimeter or micro-volts per meter.

E is usually expressed in micro-volts per meter written $\mu V/M$

$$E = 3 \times 10^{10} H \frac{\mu V}{M}.$$

The e.m.f. induced in a coil by the magnetic field is $e = AH 2\pi n/10^8$ volts where A is the area of coil and n is the frequency.

The e.m.f. induced in a vertical antennae of height h , is the number of lines cut per second, $e = hvH$ abs, or $e = Eh$ abs, or instead of absolute units the e.m.f. may be expressed in micro-volts, if h , height, is expressed in meters instead of centimeters.

The received current can be determined by dividing the e.m.f. in volts by the resistance of coil or antenna.

From these fundamental equations Dellinger's four equations¹ for received current can be obtained. They are:

From antenna to antenna

$$I_r = 188 h_s h_r I_s / R \lambda d$$

Antenna to coil

$$I_r = 1184 h_s h_r l_r N_r I_s / R \lambda^2 d$$

Coil to antenna

$$I_r = 1184 h_s l_s h_r N_s I_s / R \lambda^2 d$$

Coil to coil

$$I_r = 7450 h_s l_s h_r l_r^2 N_s N_r I_s / R \lambda^3 d$$

where h is the height, l is the length, n is the number of turns of coil, I is current in amperes, R is resistance in ohms, λ is wave length. The subscripts s and r , refer to the sending and receiving stations respectively. The lengths may be in centimeters, meters, feet or miles, provided all lengths are measured in the same unit. These formulae are for radiation. Induction must be calculated from other formulae.

The height, h , is the effective height of the antenna aerial. In the original equation, $I \cos \theta / r^2$, we assumed that the value of $\cos \theta$ was unity, and again we assumed that all the current flowed to the top of the aerial. Since we know the capacity at the top is distributed and not bunched, we know that the height will in general be less than the measured height. The effective height is the height of a theoretical aerial with all the capacity at the top and one in which all the alternating current flows from bottom to top and which will

¹J. H. Dellinger. Scientific Papers, Bureau of Standards, No. 354, p. 463.

produce at a distant point the same field as the aerial in question. However, the distant point must not be too far removed, since there is always a certain amount of absorption by intervening objects which diminishes the intensity at a great distance. The "distant" point should be a few wave lengths removed from the aerial, one wave at least. With small power the distance may of necessity be a fraction of a wave and may be so close that the field is mostly induction field, in which case the exact distance as measured is at best an approximation. There seems to be some confusion in the definition of h . Some use h as the distance from the ground to the "top", others use h as twice this distance, arguing that the earth being a good conductor will reflect and give the same effect as an aerial in free space with the center of the aerial being the point of connection to the ground. Practically this confusion does not make much difference since the height, h , must be determined experimentally.

The height, h , is determined by winding a coil or loop of rather large dimensions or diameter, and connecting a tuning condenser and a radio frequency milliammeter in the circuit and measuring the received current when the coil is placed at a distance, d , from the aerial. The area is calculated from the formula $A = n\pi r^2$ if circular, or nhl if rectangular, n being the number of turns, r the radius of the coil, h , l , being the dimension of the rectangle. The resistance can be measured by the resistance variation method if a radio frequency resistance box is available, or by the reactance variation method if the capacity of the condenser is known.

From the received current when the coil is in resonance, and resistance of the circuit, the e.m.f. is calculated. From the e.m.f. and the area the field is calculated. From the field and the distance from the aerial and the current

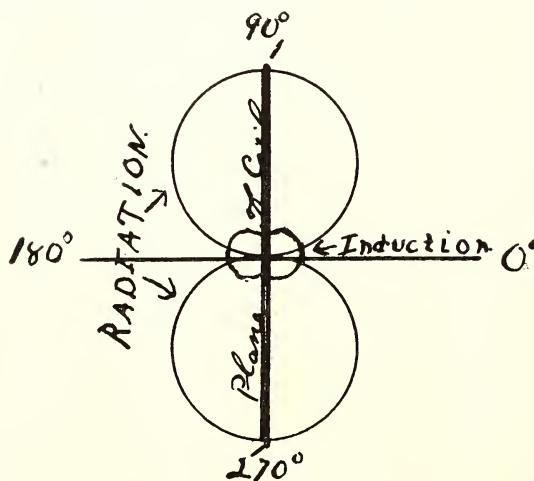


Fig. 12—When the distance is as great as one-half a wave the induction is relatively small and can be neglected.

in the sending aerial, the height, h , is calculated, assuming the equation which gives the value of the field at the given distance. If the distance is less than $\frac{1}{2}$ wave length it will be necessary to take the induction into account. Figure 12 gives the distribution of radiation and induction when $d = \lambda/2$. If the distance is less than one-sixth of a wave, the field is mostly induction. It will be well to assume an approximate value of the height, h , and calculate both the radiation and the induction for the point. From the larger, and the error which will be made if one is neglected. Of course, use the larger of the two if one is discarded.

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If the values are of the same order, then since they are in time quadrature the effective field is the square root of the sum of the squares. If the ratio of one to the other is one to two, then the received field is $\sqrt{1^2 + 2^2} = 2.24$. If the smaller value is neglected the error is more than 10%. If the relative values are one to four, then $\sqrt{1^2 + 4^2} = 4.13$. The error is 3 per cent. If the ratio is one to ten, then $\sqrt{1^2 + 10^2} = 10.05$. The error is $\frac{1}{2}$ per cent. When the ratio is one to seven the error is 1 per cent. Taking other errors into account, one can neglect the smaller without appreciable error when the smaller is not greater than one-fifth of the larger.

If it is necessary to place the coil near the aerial to get enough received current to read accurately, there is a question when the distance, d , is measured. The induction from an antenna varies inversely as d^2 . The center of "gravity" of the field is not at the center of the coil. Unless the distance, d , is rather great, there will be an error in placing the coil. If the radiating aerial is a coil, then the induction varies inversely as the cube of the distance and the error will be greater if the distance is measured from the center of the coils. If the distance, d , is great compared to the dimensions of the coil, the error will become negligible. Then the question arises, why not make the coil of small dimensions with a large number of turns?

We are trying to get as large value of the received current as possible. Since we are working with a particular frequency there is a maximum value of inductance which the coil can not exceed.

The received current depends upon the area, A , n times the area of one turn, and inversely upon the resistance of the coil. A little practical experience with receiving coils will convince one that with a given inductance A/R is a maximum when the coil is made with a small number of turns and large diameter—one turn if practical to handle.

Assuming we have readings which are practically correct, then the height, h , of the transmitting aerial can be calculated.

After knowing the effective height of the transmitter the field at other points can be calculated. A receiving antenna can be erected and the received current in the antenna measured as well as the resistance of the antenna. Knowing the current, resistance and field, the effective height of the receiver can be calculated from the formula $E = I/R = Hvh$, $h = I/RHv$. The height h , can be assumed to be constant for frequencies which do not differ greatly from the frequency used in the above determination. If the determination is made at 300 meters the same value of h can not be used at 40 meters.

If the antenna is a directive aerial such as an $\square$ aerial, the field will be different in different directions. The current should be measured at several points distributed around the aerial and the mean value of h used.

Effective height of a Coil. The effective height of a coil is the theoretical height of an antenna in which the received e.m.f. will be the same as that received in the coil. One in which the received current is the same assuming the resistance of the coil and antenna to be the same. One can get an idea of the effective height of coils from the following table:

EFFECTIVE HEIGHT OF COILS²

Turns	Diameter	Frequency	Effective Height
4	44.2	4.9 x 10 ⁶	6.3 cm.
4	44.2	5.4	6.9
4	44.2	7.8	10.0
2	35.0	8.6	3.5
2	35.0	16.1	6.5
2	35.0	17.0	6.8

Instead of a milliammeter in the circuit a tube voltmeter can be used to measure the Pd across the condenser.

$$Pd = ILw = I/Cw, \text{ since } I = E/R, E = PdR/Lw = Pd R C w.$$

With a tube, voltmeter readings can be made at a greater distance. However, the resistance of the circuit is increased when the voltmeter is used. It is necessary to measure the resistance with the voltmeter connected.

TABLE SHOWING CHANGE OF EFFECTIVE HEIGHT WITH WAVE LENGTH

Turns	Area	Frequency	Effective Height	Wave Length
8	88 x 88	.6 x 10 ⁶	7.8 cm.	500 meters
8	88 x 88	1.0	13.0	300
8	88 x 88	1.5	19.4	200
2	56 x 56	10.0	13.0	30
2	56 x 56	7.5	9.9	40
2	56 x 56	3.0	4.96	100

In the above tables it will be seen that the height of a coil is very small. This is partly overcome by the fact that as a general thing it is much easier to get a coil of small resistance than it is to construct an antenna of low resistance. A coil is also usually more portable than an antenna.

²Friis and Bruce. Inst. Rad. Eng. Proc. 14. 518, 1926.

MECHANISM OF A CONDENSED SPARK DISCHARGE.

HARVEY A. ZINSZER, Hanover College.*

Considerable work has been done recently on the electric spark discharge by the engineering profession with a view of eliminating corona discharges and of devising adequate protection against steep wave-front impulse discharges.

Perhaps the most noteworthy results to be obtained along these lines is the work of McEachron and Wade,¹ who were the first to report successful instantaneous oscillographs of condensed electric discharges of frequencies as high as 20,000 kilocycles and at potential differences of approximately 100 kilovolts. The oscillographs showed that the first oscillation of these powerful discharges was approximately rectangular in shape and contained by far the greater part of the energy in the wave-train, the main transient of which usually attained its maximum value in about 0.4 microseconds.

Another interesting report along similar lines is Bulletin No. 19 of the Engineering Experimental Station, Purdue University, entitled "A Photographic Study of High Voltage Discharges." This bulletin is a second progress report on the investigation of the electrical fixation of atmospheric nitrogen and represents the results of several methods of attack used to determine the mechanism and characteristics of the corona discharge.

Other interesting publications on the more general properties of the spark discharge have also appeared. Several of these latter reports are rather closely related to the engineering aspect of the problem. One, the work of Anderson² on electrically exploded wires, shows that the energy dissipated within the spark interval of about 10 microseconds is approximately 30 calories, which expended into a mass of 2 mgs. should have raised its temperature to about 300,000 degrees centigrade but based upon the intrinsic temperature corresponded to about 20,000 degrees centigrade. Using a ballistic pendulum arrangement, Anderson determined the pressure produced by his spark discharge as being approximately 40 atmospheres.

Another study of the latter type was a report by the writer³ on "The Shadowgraph Method as Applied to a Study of the Electric Spark," in which instantaneous photographs were obtained for various disposi-

* The investigation on which this article is based was made in the Physics Laboratory of Indiana University under the direction of Dr. A. L. Foley, to whom the writer is indebted for his assistance and counsel throughout the experiment.

¹ General Electric Review 28, 622, 1925.

² Astrophys. Jour. 51, 37, 1920.

³ Dissertation: "The Shadowgraph Method as Applied to a Study of the Electric Spark," executed at Indiana University, 1926; Phil. Mag. 32, 1098, 1928, abstract in Phys. Rev. 29, 752, 1927.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

tions of capacity and inductance. It is upon the results of this work substantiated by such reports as have just been mentioned that the proposed theory of a condensed electric discharge contained herein is developed.

Theory of the Condensed Electric Discharge. M. Toepler⁴ showed that an electric discharge between a point and a plane frequently commences with a dark discharge and ends with an arc, providing the potential difference is sufficiently increased and maintained. A graphic representation of Toepler's spark discharge appears in figure 1. Here the abscissas represent current and the ordinates represent potential difference.

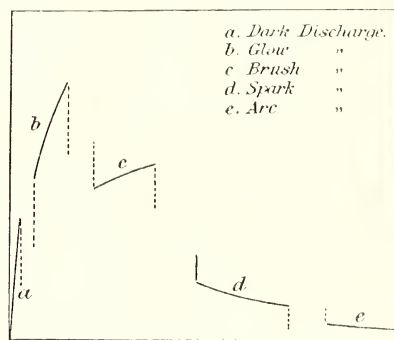


Fig. 1—A graphic representation of Toepler's spark discharge.

The following theory, however, is based upon the behavior at atmospheric pressure of a normal condensed discharge between points. If one will include the mechanical phenomena occurring in such a discharge, the sequence of the various stages of the discharge will be: (a) dark discharge; (b) glow discharge; (c) brush discharge; (d) spark discharge; (e) sound pulse; (f) striations; and (g) gases and vapors. The writer will consider each of these separately.

(a) **Dark Discharge.** Due to the increasing electric field set up between the terminals of a spark gap connected to a charging condenser, it would seem logical to believe that all charged air particles due to "natural ionization," and coming under the influence of the increasing field, should be gradually drained to their respective poles. This movement of charged bodies whose momentum is constantly increasing constitutes the dark discharge. Faraday⁵ discovered its existence from the increased lag which an electric discharge exhibits when a magnet is brought in the vicinity of a gap region through which such a discharge is taking place. Nipher⁶ likens a dark discharge to the trans-

⁴ Ann. d. Phys. 7, 477, 1902.

⁵ Faraday: "Experimental Researches," No. 1417; No. 1544.

⁶ Nipher: "Experimental Studies in Electricity and Magnetism," Blakiston, (Philadelphia) 1914, p. 5.

portation of negative corpuscles across the gap space by supercharged molecules.

(b) Glow Discharge. A stage is eventually reached when in addition to the charged particles flowing from various points in the gap region and uniting in "drainage" channels as they proceed to their respective poles, a glow discharge takes place in the form of electrons ejected from the negative terminal. The glow may, however, be two-fold, a negative and a positive glow, the former due to the combining effect of electrons ejected from the negative terminal with positive ions; the latter to the deliverance of electrons to the positive terminal from adjacent air molecules. Thus, one would expect a greater luminescence at the positive than at the negative terminal because the electrons being lighter and having a shorter distance to travel, exist in greater abundance about the positive terminal than do the derived positive ions about the negative terminal. Nipher⁷ suggests that the scintillations frequently visible at the positive terminal of a glow discharge are the beginnings of the drainage streamers of a brush discharge.

(c) Brush Discharge. Let us now conceive of individual air molecules as being polarized by the action of the electric field and arranging themselves in narrow chain-like aggregations, like smoke and dust do under similar circumstances. These aggregations being bodies of high specific inductive capacity will act on the field like pointed conductors, with a consequent concentration of electric lines of force on the ends of the chain so that the maximum electric force will be considerably greater than the average force which we ordinarily measure.

Simultaneous with the above we should by this time expect ionization by collision on the part of the more rapidly moving ions. Thus it is mainly due to these two agencies that the brush discharge takes on its form. Faraday⁸ found that when two equal spheres discharge their electricity by a brush discharge into air, the discharge occurs at a lower potential for the negative ball than for the positive; meaning that more electricity accumulates on the positive ball than on the negative before the occurrence of the discharge. Thus when the positive discharge does take place it is finer than the negative.

(d) Spark Discharge. If the brush discharge is sufficiently abrupt, it will blend with the initial or pilot spark of the principal series of electrical oscillations known as the main spark discharge. For it is the brush discharge, preceding the initial discharge and burning its way along a molecular thread of charged air and dust particles of considerable resistance, which develops the required amount of heat necessary for spontaneous ionization of the air in the gap region. The disruption of the air by the initial discharge gives rise to a sound pulse which travels but a few millimeters during the entire life of the spark and which is accompanied by considerable pressure. The heat developed by the initial discharge volatilizes some of the electrode metal, with the result that subsequent oscillations take place in the vapor of the metal which seemingly diffuses into the gap region under forced pressure.

⁷ Nipher: loc. cit. (6) p. 7.

⁸ Faraday: loc. cit. (5) No. 1501.

With certain dispositions of apparatus, globules or molecular aggregations are literally projected from the electrodes into the gap space, while under other conditions the discharge may terminate in a bright glow at each terminal.

This procedure was first observed by Trowbridge,⁹ who made photographic studies of the spark discharge by means of a rotating mirror. It was further corroborated by Schuster and Hemsalech,¹⁰ who photographed the spectrum of the spark by means of a rotating mirror device and found that the initial discharge consisted of air lines while the

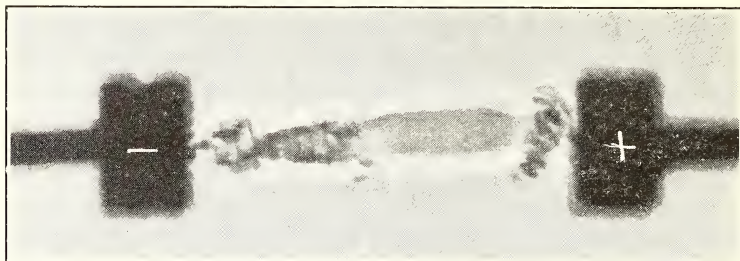


Fig. 2—Vapor is diffusing under forced pressure into gap space.

main electrical oscillations consisted of vapor lines. Figure 2 exemplifies the case where a gradual diffusion of the vapor takes place into the gap space; figure 3 represents the condition where the vapor is projected into the gap space in the form of globules and molecular aggregations; and figure 4 represents the case where a discharge terminates in a glow.



Fig. 3—Vapor being projected in form of globules and molecular aggregations.

(e) Sound Pulse. The origin of the sound pulse, which is a compression wave, has already been indicated under the preceding discussion. It has its inception with the striking across of the pilot spark, the latter being a consummation of the total brush discharge. It is

⁹ Phil. Mag. 36, 343, 1893.

¹⁰ Proc. Roy. Soc. 64, 331, 1899.

then that the air in the gap region is subjected to an enormous strain due to the tremendous heat which is suddenly developed. The layers of air coming under the influence of this heat expand in an exceedingly brief space of time and leave the core of the tube which extends across the gap space in an evacuated condition. Thus as the jerk of a whip as it cuts the air produces a vacuum and the rebound of the air as it fills the vacuum creates a sound disturbance, so the tube of hot rarefied gas gives birth to a sound pulse. The sound pulse, however, being a mechanical phenomenon, will not mature until the electrical oscillations have decayed.

This phase of the electrical spark already received considerable attention shown by the work of A. Toepler,¹¹ Mach,¹² Wood,¹³ M. Toepler,¹⁴ and Foley.¹⁵ The photographs by the writer show very plainly that the



Fig. 4—Discharge terminates in glow at positive terminal.

velocity of the sound pulse exceeds the rate of dissipation of the hot gases. An interesting sound pulse appears herewith. Figure 5 represents a heavy discharge. Based upon Professor Foley's¹⁶ work on "Instantaneous Velocities of Spark Waves," the latter spark is about 35 microseconds old; furthermore, this spark also enables us to estimate the period of exposure of these shadowgraphs as being of the order of 3 microseconds.

(f) Striations. With the dissipation of the electrical energy due to heat developed in the metallic circuit and the spark gap; to insulation losses of the condenser and of the remainder of the circuit; to brush leakage of the condenser; to eddy currents induced by the alternating magnetic field; and, to electromagnetic radiations, the tube of hot gas and vapor extending between the gap terminals and serving as the carrier of the electric oscillations now extinct, will become singularly affected by laminal aggregations of supercharged particles which are urged away from or attracted to oppositely charged terminals without

¹¹ Pogg. Ann. 131, 33, 1867.

¹² Sitz. d. Wien Akad. 98, 1333, 1889.

¹³ Phil. Mag., 48, 218, 1899; 50, 148, 1900.

¹⁴ Ann. d. Phys. 41, 838, 1904; 27, 1043, 1908.

¹⁵ Phys. Rev. 35, 374, 1912.

¹⁶ Phys. Rev. 16, 449, 1920.

an appreciable interchange of charge. Since we know that a negative and a positive region can exist adjacent to one another, for example, the dark and luminous columns of a discharge tube, the conjecture might be made that the carriers are returning to regions of more stable equilibrium after having delivered all of their supercharge and perhaps a part of their normal charge. Hence these alternately dark and luminous regions may under the proper conditions exist as striations which can quite properly be interpreted as electrically produced sound waves of very short wave lengths.

Thus, M. Toepler¹⁷ found that the discharge of an induction coil through the flame of a candle gives a bright discharge traversed by dark spaces. Earlier, A. Toepler¹⁸ in a stroboscopic investigation of the air produced by the passage of the electric spark found regions of

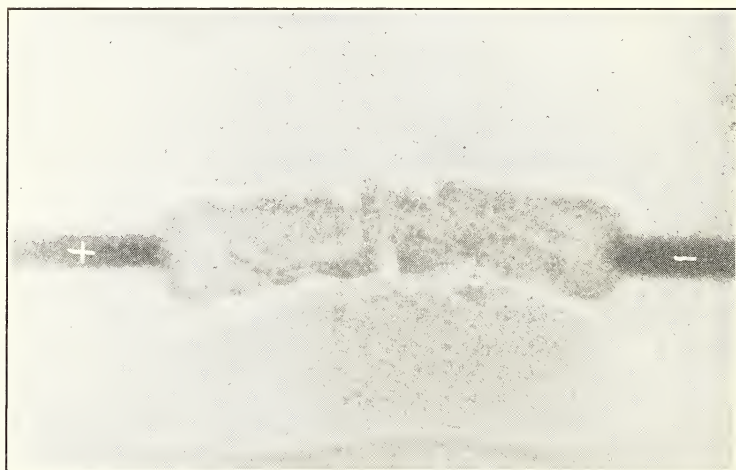


Fig. 5—Sound pulse resulting from a heavy discharge.

periodic swellings and contractions as if the centers of greatest disturbance were distributed at regular and finite intervals along the line of discharge. It remained, however, for Paalzow¹⁹ to discover the necessary conditions for the appearance of striations. He found by discharging a Leyden jar through a vacuum tube that whenever the resistance of the discharge circuit was less than a certain critical value, the image of the spark was seen as a series of separated bars of light and the discharge tube showed by the identity in the appearance of the glow light at the two terminals that the discharge was bi-directional. Hence it would appear that with the expulsion of the sound wave, the gap region exists in a state of low pressure; and, if the pressure is

¹⁷ Wied. Ann. 63, 109, 1897.

¹⁸ Pogg. Ann. 134, 194, 1868.

¹⁹ Pogg. Ann. 112, 567, 1860; 118, 178, 1861.

sufficiently low and the resistance of the gap circuit less than the critical value referred to above, striations will result. Nipher²⁰ explains the existence of striae in the positive column of the Geissler tube as being electrically produced air waves, the adjoining halves of which are Faraday dark spaces and conducting columns. Figure 6 shows a rather ancient striated spark known as the "caterpillar type," due to a weak

²⁰Nipher: loc. cit. (6) p. 47.

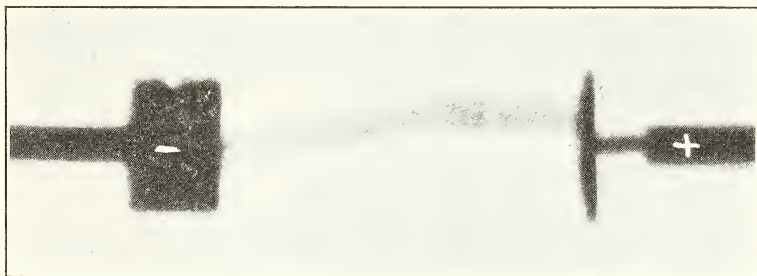


Fig. 6—Striations in an ancient spark due to a weak discharge.

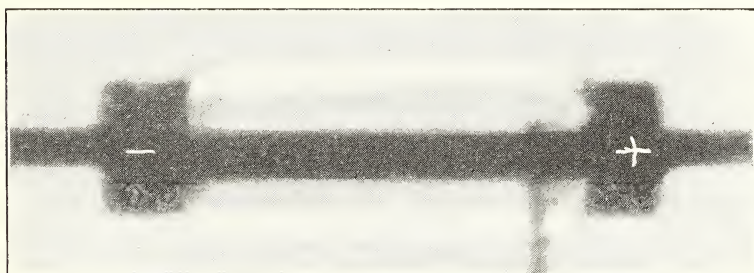


Fig. 7—Clearly defined striations of millimeter widths due to a strong discharge.

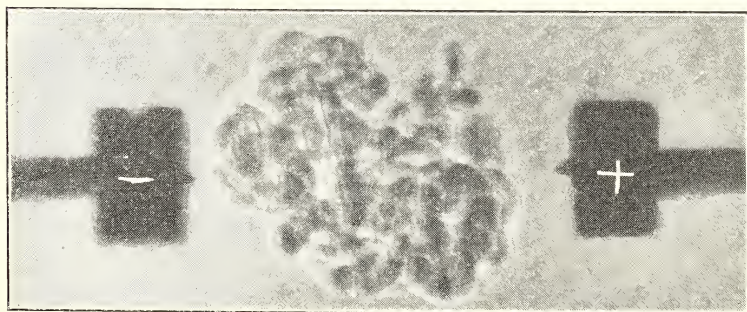


Fig. 8—Regular diffusion of gases and vapors in a normal discharge after all electrical and other mechanical phenomena have subsided.

discharge; while figure 7 represents a strong discharge and shows clearly defined striations of approximately 1 mm. widths.

(g) Gases and Vapors. With the emergence of the sound pulse, the cessation of the striation-vibrations and the readjustment of the air pressure in the gap space, the hot gas in this region tends to fulfil one of the fundamental properties of all gases, namely, diffusion. A peculiarity of the mode of diffusion as exhibited by figure 8 is the momentum acquired by these columns or tubes of hot gases and vapors.

VELOCITY OF SOUND IN FREE AIR.

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In the preparation of data for publication in the International Critical Tables the writer spent a great deal of time in the study of the literature on the question of the velocity of sound in free air. Inasmuch as only a few of the results are to be published in the Tables, it is thought worth while to publish all of the data in the Proceedings of the Indiana Academy, as follows:

Velocity	Authority	Method
332.0	Committee, Academy of Science, Paris ¹ , 1738.....	Flash and sound of cannon
331.2	Committee, Bureau of Longitude, Paris ⁵ , 1822.....	Gun flash and sound
332.25	Moll and Von Beek ¹⁷ , 1823.....	Flash and sound of cannon
333.00	Dulong ⁸ , 1829.....	Variable length organ pipe
332.37	Bravais and Martins (Faulhorn) ⁴ , 1844.....	Reciprocal gun firing. Stations at different levels
331.33	Wertheim ²⁷ , 1844.....	Organ pipes
330.66	Le Roux ¹⁴ , 1862.....	Tubes and chronoscope
331.37	Regnault ¹⁸	Reciprocal gun firing, distance 1280 and 2445 m.
330.71	Regnault, Paris, 1864.....	Air in very large tubes
330.6	Regnault ¹⁸ , 1866.....	Gun and electric chronograph
332.40	Stone (Cape Town) ²² , 1871.....	Bosscha's interferential method
331.57	Szathmari ²³ , 1877.....	Kundt's tubes
331.68	Blakley ³ , 1884.....	Fork and short resonance tubes
331.32	Stevens ²¹ , 1898.....	Gun and chronometer, also electric chronograph
330.7	Frot ¹¹ , 1898.....	Water pipes and manometric capsule
331.36	Violle ²⁵ , 1900.....	Average of weighted results of previous investigators
331.78	Rowland ¹⁹ , 1902.....	Water pipes and manometric capsule
331.15	Violle, Vautier ²⁶ , 1905.....	Telephone transmitters and parabolic reflectors
331.29	Hebb ¹³ , 1905.....	Closed resonator
331.41	Hebb, 1919.....	Kundt's tube, Poulson arc, frequencies up to 800,000
331.92	Thiesen ²⁴ , 1908.....	Kundt's tube
331.0	Dieckmann ⁶ , 1908.....	Guns. Electric acoustic detector
331.9	Schweikert ²⁰ , 1915.....	Artillery. Phonodeik detectors
330.96	Eschlangon ⁹ , 1918.....	Gun and microphones
330.86	Miller, D. C. ¹⁶ , 1918-19.....	Air in tube. Electric chronograph
330.80	Angerer and Ladenburg ² , 1921.....	Thiesen method corrected
328.6	Dixon, Campbell and Parker ⁷ , 1921.....	Steam whistle and chronograph
331.57	Grüneisen and Merkel ¹² , 1921.....	Average of the weighted results of Rowland and last ten observers listed above
332.11	McAdie ¹⁵ , 1922.....	
331.45	Foley ¹⁰ , 1925.....	

The above chronologically arranged table indicates a more or less gradual time decrease in the velocity of sound as experimentally determined. The weighted average of 331.78 meters per second obtained by Rowland in 1902, and of 331.45 by the author of this paper in 1926, would seem to be too discordant to be attributed wholly to experimental errors. The decrease is more strongly suggested by comparing data obtained when the experimenters were using the same, or practically the same, methods. For instance, the

Average of Cannon Flash Methods

1738 to 1828 = 331.95

1848 to 1905 = 331.48

1918 and 1919 = 330.87

In a paper on "A Photographic Method of Finding the Instantaneous Velocity of Spark Waves," (10) the writer cites his own work and that of others who have shown that the velocity of a very loud sound wave at points *very near* the source, and therefore where the molecular displacement is relatively large, is much higher than at points farther removed. The results obtained by Miller in 1918 and 1919 were corrected for this abnormal velocity, which doubtless explains a part of the decrease his results seem to show. It would appear, however, that not all the decrease is so explained, for the results obtained by earlier experimenters were generally over such great distances between the sound source and the observing station that the abnormal velocity near the former would have had little effect on the average over the entire range.

A very slight change in the constitution of the atmosphere, either in the ratio of the nitrogen and oxygen content, or in the CO₂ or other "impurities" present, would explain the decrease.

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THERMAL CONDUCTIVITY OF CONDENSING VAPOR FILMS.

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An investigation of the transfer of heat through a series of resistances shows that often a large proportion of the total temperature drop occurs at the boundaries of a conductor and not through its mass proper. For example, if we investigate the temperature gradient in an air preheater heated by flue gas, we will find that no appreciable temperature drop occurs through the metal wall of the heater and that temperature changes throughout the air or flue gas are nearly equalized by convection currents. In this apparatus nearly the entire temperature drop occurs at the inner and outer surface of the metal. The cause for the large temperature referred to is the presence of a stationary film of the fluid, flue gas or air on the surface of the solid and through which heat must be transferred by the process of conduction. Convection does not take place in this adsorbed layer owing to the lack of freedom of motion, and since gases are very poor conductors of heat the film has a high thermal resistance.

It is the purpose of this paper to report the results of some investigations conducted on the thermal conductivity of one particular fluid film. The film studied was a condensing vapor film such as exists in any condenser tube. The particular substance investigated was carbon tetrachloride. The sketch of the apparatus is shown in figure 1 and consists of a boiler connected to a copper tube water jacketed condenser and accessories. The two Liebig glass condensers condensed the excess vapor not condensed in the copper tube, as it was desirable to have the entire length of the copper tube active in condensing vapors. The experimental procedure consisted, briefly, in distilling a quantity of carbon tetrachloride in a measured length of time and determining the temperature drop through the film and tube by means of thermocouple measurements of the temperature of the outside of the copper tube. For this purpose three pairs of chromel and copel wires were soldered to the outside of the copper condenser tube. A Leeds and Northrup potentiometer, range 0 to 16 millivolts, was used to read the potentials set up at the thermocouples.

During the runs, which lasted from 30 to 80 minutes, the potential at each thermocouple was read every three minutes. Table I shows the recorded values of Run No. 4. The figures show that fairly constant readings were obtained.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

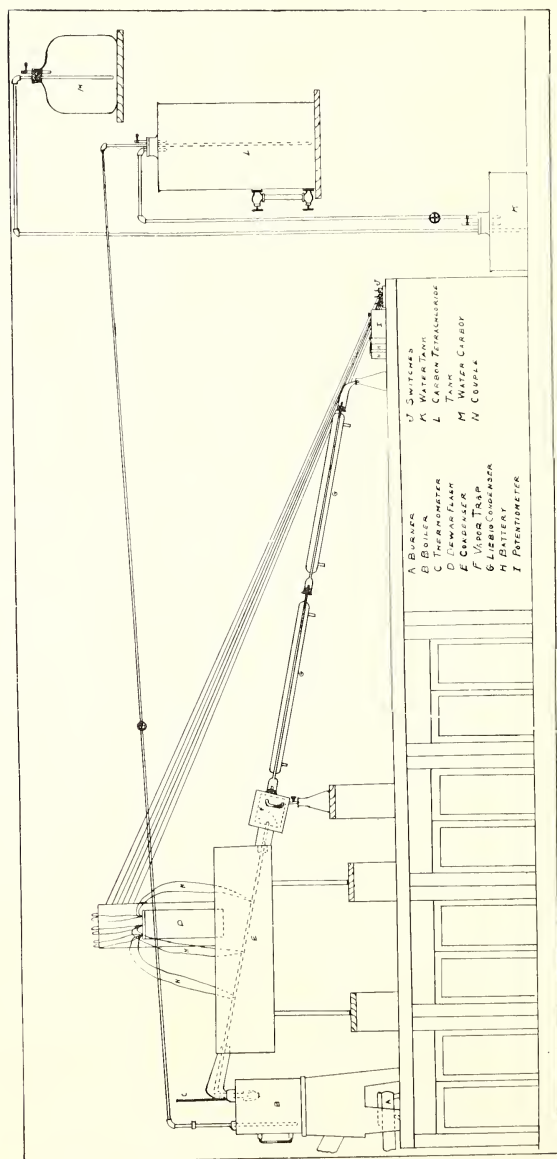


Fig. 1—Diagram of apparatus used in studying thermal conductivity of condensing vapor films.

TABLE I.—Recorded values of Run No. 4.

Couple 2	Couple 2	Couple 2
3.12	3.08	2.87
3.12	3.08	2.87
3.11	3.07	2.87
3.11	3.06	2.84
3.11	3.08	2.83
3.11	3.07	2.81
3.11	3.07	2.79
3.10	3.07	2.75
3.09	3.05	2.75
3.09	3.04	2.73
3.09	3.03	2.72
3.08	3.03	2.71
3.07	3.03	2.71
3.07	3.03	2.71
3.07	3.03	2.70
3.05	3.03	2.69
3.07	3.03	2.69
3.07	3.03	2.69
3.04	3.00	2.64
3.07	3.03	2.66
3.04	3.00	2.63
3.03	2.99	2.63
Average		
3.085	3.042	2.742
Corresponding Temperature from Calibration Curves in degrees Centigrade		
68.65	67.3	60.62

Average Temperature in degrees Fahrenheit, 149.94.

Weight condensed in copper condenser, 10485.8 grams.

Weight condensed in Liebig condenser, 17891.8 grams.

Length of run, 63 minutes.

The thermocouples had previously been calibrated by filling the jacket with water, the temperature of which was measured by mercury thermometers. Calibration readings were made every five degrees. The results of nine runs are shown in Table II.

TABLE II. Results of nine runs of calibration readings.

Run	θ	Cu. Condensate in grams	Liebig Condensate in grams	W_1	W_2
2	80/60	28,491.6	8,992.1	47.2	14.85
3	80/60	19,207.3	18,193.8	31.75	30.1
4	63/60	10,485.8	17,891.8	22.05	37.55
5	58/60	10,054.1	18,208.1	22.95	41.5
6	30/60	6,571.4	5,373	28.95	23.7
7	60/60	13,488.4	6,747.9	29.7	14.85
8	56/60	13,021.6	14,486.2	30.7	34.2
9	36/60	7,692.3	9,952.2	28.25	36.6
10	45/60	9,785.7	11,907.1	28.7	35.0

The quantity of liquid condensing in the copper condenser and also that condensing in the Liebig condenser was weighed. The heat transferred through the copper tube was calculated from the known heat of condensation of carbon tetrachloride. The area of the tube was of course calculated from careful measurements of its length and diameter. (Table III.)

TABLE III. Calculated results of experiments.

Run	$\frac{Q}{\theta}$	Δt	V	H	h_v
2	3,935	53.5	10.23	263.5	264.5
3	2,655	33.8	12.25	280.5	281.5
4	1,839	19.76	12.92	333.3	335.0
5	1,918	18.18	14.12	377.9	380.0
6	2,420	31.62	10.15	274.0	275.2
7	2,482	33.9	7.91	262.2	263.2
8	2,572	31.1	13.34	296.2	297.5
9	2,360	30.82	13.50	274.5	275.8
10	2,403	32.9	13.14	261.7	262.7

The values of the conductivity of the condensing vapor film vary from 262.7 to 380. Table IV gives the numerical values of the constants of the apparatus and of carbon tetrachloride.

TABLE IV.—Numerical values of the constants of the apparatus and of carbon tetrachloride

CALCULATED CONSTANTS

a.....	0.001043
A_1	0.2792
A_2	0.3291
A	0.3042
d_1	0.03643
d_2	0.0429
k_{Cu}	220
L	0.003255
N	2.44
Boiling point of carbon tetrachloride.....	169.7° F.
Heat of Vaporization.....	83.52 B. t. u./lb.

The nomenclature used in this article conforms with common usage and is explained by Table V.

TABLE V.—Nomenclature Used.

<i>Symbol</i>	<i>Meaning</i>	<i>Units</i>
a.....	Cross-sectional area of copper tube.....	Sq. ft.
A ₁	Inside area of copper tube.....	Sq. ft.
A ₂	Outside area of copper tube.....	Sq. ft.
A.....	Arithmetic mean area of copper tube.....	Sq. ft.
d ₁	Inside diameter of copper tube.....	ft.
d ₂	Outside diameter of copper tube.....	ft.
H.....	Overall coefficient of conductivity.....	B.t.u./hr./sq. ft./° F.
h _v	Condensing film coefficient of conductivity.....	B.t.u./hr./sq. ft./° F.
k _{Cu}	Coefficient of conductivity of copper.....	B.t.u./hr./sq. ft./° F./ft.
L.....	Thickness of copper tube wall.....	ft.
N.....	Length of effective condensing surface of copper tube.....	ft.
Q.....	Quantity of heat transferred through copper tube.....	B.t.u.
Δt.....	Temperature difference (vapor to outside of copper tube)....	°F.
V.....	Mass velocity (average).....	lbs./sec./sq. ft.
W ₁	Weight of condensate from copper tube.....	lbs./hr.
W ₂	Weight of condensate from Liebig Condenser.....	lbs./hr.
θ.....	Time.....	hrs.

THE CALIBRATION OF RADIO FREQUENCY GALVANOMETERS AND MILLI-AMMETERS.

J. B. HERSHMAN, Indiana University.

There are numerous methods for calibrating high frequency galvanometers. The purpose of this paper is to add to the list a simple accurate method for calibrating such an instrument at any particular frequency or at all frequencies.

In making a study of the applications of a thermionic voltmeter to high frequency measurements, a method of calibration similar to the direct current, resistance, potential method occurred to the writer. A vacuum tube voltmeter is used to measure the fall of potential across a standard high frequency resistance in series with the galvanometer to be calibrated, in a high frequency measuring circuit. If the hot wire

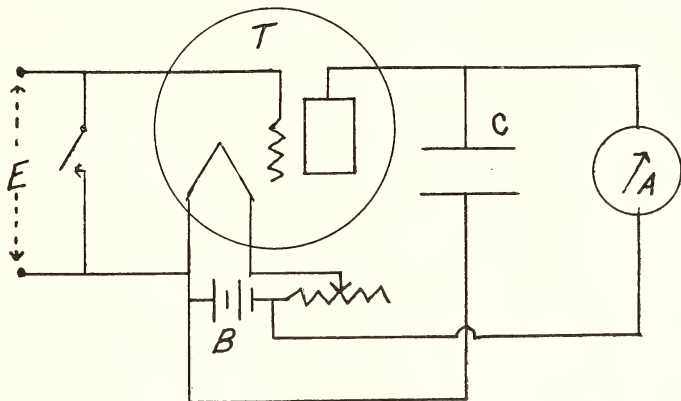


Fig. 1—Diagram of a simple vacuum tube voltmeter.

of the galvanometer or the heater wire of the couple is of such dimensions as to have a negligible difference of resistance over a relatively wide range of frequencies, the meter can be calibrated at a median frequency with a high degree of accuracy for a given range. If the radio frequency resistance of the meter varies, the calibration can readily be made for any particular frequency.

The sources of error in high frequency measurements of current are discussed in detail in Circular 74 of the Bureau of Standards and a careful résumé of the subject is made by Herbert Hazel in the Proceedings of the Indiana Academy of Science, volume 36, page 145. Most of the errors mentioned are eliminated in the method outlined below, since the calibration is made under the same conditions at which the galvanometer or milli-ammeter is used.

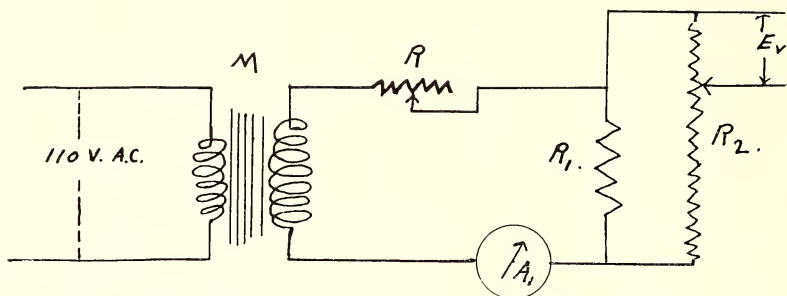


Fig. 2—Suggested type of A. C. calibration potentiometer.

It has been shown by Brown and Colby of the High Frequency Laboratory at the University of Texas, and others, that with certain types of thermionic voltmeters the calibration is independent of frequency.

The writer has investigated this point for the particular circuit used in the voltmeter described in figure 1, and has found that the 60 cycle and the 1000 kilocycle calibration curves are identical.

A detailed diagram of the simple voltmeter is given in figure 1. T is a 201A type vacuum tube; C, a 1 mfd. by-pass condenser; A, a micro-ammeter or calibrated galvanometer; B, a six-volt storage cell; E, potential terminals of the voltmeter. A is given an initial reading of 40 micro-amperes with E equal to zero, then a 60 cycle calibration curve may be made from .2 volt to 2 volts, using some type of A. C. potentiometer.

It is necessary that the filament current remain fairly constant and the zero reading of the plate micro-ammeter is a more reliable check on this current than a milli-ammeter in the filament circuit.

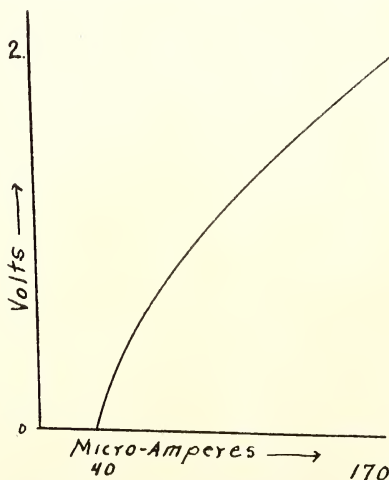


Fig. 3—Calibration curve for vacuum tube voltmeter.

Figure 2 gives a suggested type of calibrating circuit which was used by the writer. However, any scheme for giving accurately a known A. C. voltage can be used. M is a 110-5 volt A. C. transformer furnishing a current, measured by A , through a rheostat R to a standard one ohm, non-inductive resistance R_1 , across which is a potentiometer R_2 . The voltage E may then be applied to the potential terminals of the voltmeter and a curve similar to figure 3 is obtained.

In figure 4 the measuring circuit LC_1R is coupled to a radio frequency oscillator inducing a current in the circuit. If R_h is a standard, variable, high frequency resistance or a standard set of resistances made according to the specifications of the Bureau of Standards Circular No. 74, the current through R may be varied. The potential drop

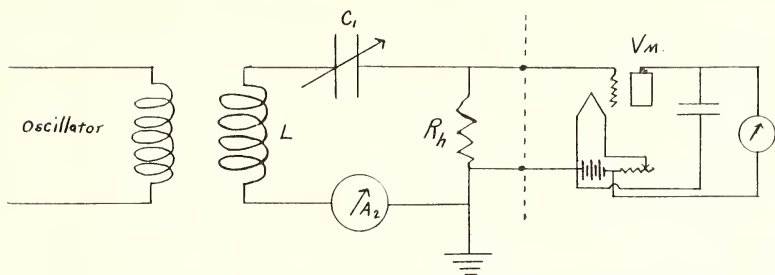


Fig. 4—Calibration circuit for radio frequency galvanometer, A_2 .

across R_h may be measured by the vacuum tube voltmeter V_m , and I may be calculated from $V=RI$. The current I may be changed by a variation of the coupling over a small range without appreciably affecting the frequency.

In conclusion, it is to be noted that this method of measurement may be applied to the determination of radio frequency currents from very small to very large values independent of frequency.

THREE ELECTRODES VACUUM TUBE OSCILLATOR, A SPECIAL CASE OF PARALLEL RESONANCE.

EUNG TYUN CHO, INDIANA UNIVERSITY

Resonance in Parallel Circuits. Two or more parallel circuits are said to be in resonance when the inductive susceptance is equal to the condensive susceptance.

Figure 1 is an electrical generator circuit in which there is a condenser and coil in parallel, and figure 2 is the vector diagram in case of parallel

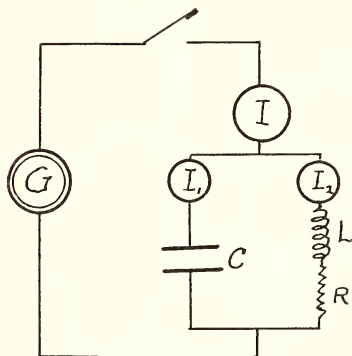


Fig. 1—An electrical generator circuit in which there is a condenser and coil in parallel.

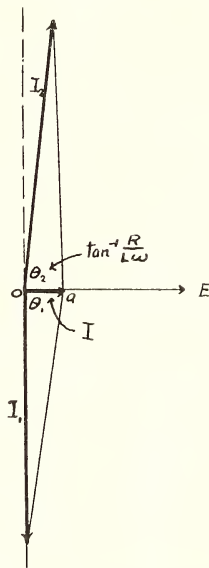


Fig. 2—Vector diagram in case of parallel resonance.

resonance, assuming that we have pure capacity and inductance a small resistance series with the inductance, L . For the figure 2 to be in resonance, I_1 must be equal to I_2 . Since $(E/Lw = ECw)$ and $I = E\sqrt{R^2 + (Lw - 1/Cw)^2} = E/R$, where R is the resistance in series with the generator. Therefore in a circuit in which resonance exists the total current, I , is equal to the current in the conductive part of the circuit, it is in phase with the total impressed E .

Assumption of Three Electrodes Vacuum Tube as Driver of High Frequency Circuit. Referring to figure 3 an assumption is made that the vacuum tube is equivalent to a generator and the regenerative or tickler circuit is equivalent to a reversing switch or commutator which does not take much energy.

Figure 4, the vector diagram is drawn from circuit 3 which is similar to figure 2.

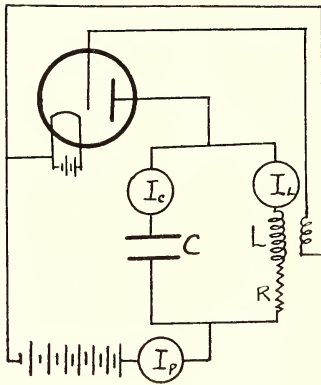


Fig. 3—A vacuum tube generator circuit.

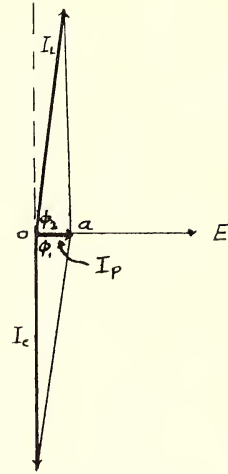


Fig. 4—Vector diagram of figure 3 which is similar to figure 2.

In figure 3, I_c is the radio frequency current through the condenser. This is numerically equal to I_L . The vector difference I_p is the radio frequency current in the plate circuit of the tube.

The current in the plate circuit consists of two currents I_p the alternating current superimposed on a direct current. The D.C. milliammeter in the circuit measures the direct current. Referring to figure 5 which gives the characteristic curve of the tube, the current when the tube is oscillating is represented by the curve which is very much like a sine curve. If this is an alternating current superimposed on a direct current, the direct current is represented by the horizontal line ab , and the maximum value of the alternating current is equal to the direct current. Then $I_p(\text{A.C.}) = I_p(\text{D.C.})/\sqrt{2}$. Thus the D.C. milliammeter can be used to give an indication of the alternating current in the plate circuit. The vector (oa) in figure 4 should be equal to the direct current divided by $\sqrt{2}$. Thus $I_p(\text{A.C.}) = I_p(\text{D.C.})/\sqrt{2}$.

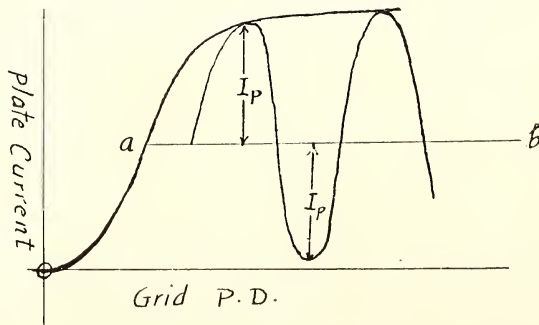


Fig. 5—Characteristic curve of the vacuum tube.

In this experiment a 201A vacuum tube is used.

From figure 4 the relationship is $I_c \tan \phi_1 = I_c RCw = I_p/\sqrt{2}$(A)

Notes:

R is the total resistance of the resonance circuit as measured by the resistance variation method.

C is pure capacity in micro farads.

w is the angular velocity = $2\pi n$, n being the frequency.

I_c is the oscillating current indication of the thermocouple type ammeter.

I_p is plate current indicated by D. C. ammeter.

The following data and calculation shows the relationship of equation (A).

Wave length in meters	Capacity (M. F.)	Resistance (R)	Tan ϕ_1 (RCw)	$I_p(\text{A.C.}) =$		
				I_c	$I_p \tan \phi_1$	$I_p/\sqrt{2}$
1000	0.00183	7.5	0.0258	116	2.99	2.00
1140	0.00206	6.0	0.0204	111	2.26	1.89
1220	0.00236	6.0	0.0220	113	2.48	1.99
1350	0.00288	6.0	0.0242	115	2.78	2.06
1490	0.00384	5.3	0.0259	115	3.00	2.37
1510	0.00358	8.6	0.0385	116	4.47	2.27
1650	0.00428	6.0	0.0293	114	3.36	2.38
1700	0.00488	6.0	0.0322	109	3.52	2.54
1780	0.00500	6.0	0.0318	107	3.41	2.60
1920	0.00582	6.0	0.0345	104	3.58	2.66
2060	0.00663	5.0	0.0305	99	3.02	1.66

The data in the last two columns should check. However the method of estimating the alternating current in the plate circuit is very crude. The check is close enough to show that the oscillating tube generator can be explained very simply by considering it to be a special case of parallel resonance.

Note: If the tube is oscillating vigorously the alternating current will be greater than $I_p(\text{DC})/\sqrt{2}$. The curve for A.C. current instead of being a sine curve will be more rectangular.

ENERGY LOSSES IN RAILROAD TRACK HAMMERS.

EDWIN MORRISON, Michigan State College.

Growing out of the publication of my article on "Energy Losses in Commercial Hammers"¹, engineers of the Richmond Division of the Pennsylvania Railroad became interested in the problem from the standpoint of energy losses in spike and track hammers. From the regular stock they submitted specimen hammers for test. These samples had previously been rigorously tested by the railroad engineers for endurance and breakdown and reported to be of the highest quality in these particulars.

The apparatus used was similar to that employed for the testing of commercial hammers. This is the same as that employed for experiment six, page 62 in Millikan's "Mechanics, Molecular Physics and Heat." A photograph of the apparatus used in testing commercial hammers is shown in figure 1.

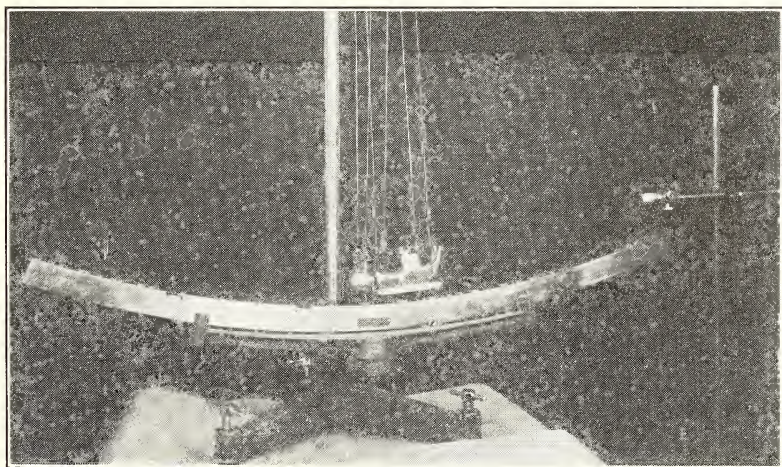


Fig. 1—Apparatus used in testing commercial hammers.

The radius of the ballastic pendulum used for the railroad hammers was about six meters, and the mass of the steel sphere was 548 grams.

The experiment consisted in displacing the hammer to a certain angular position to one side the normal position and allowing it to drop and impinge upon the steel sphere, noting the maximum angular displacement of both the sphere and the hammer after impact.

The common equations for the coefficient of restitution and the percentage loss of kinetic energy were used. For our purposes these equations as derived from figure 2 are as follows:

¹Proc. Ind. Acad. Sci., 1918.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

$$\text{Coefficient of restitution } \varepsilon = \frac{\sqrt{1 - \cos \omega} - \sqrt{\cos \alpha - \cos \beta}}{\sqrt{\cos \alpha - \cos \theta}} \quad (1)$$

$$\text{Percentage loss of K. E.} = (1 - \varepsilon^2) \frac{m_2}{m_2 + m_1} \quad (2)$$

TABLE I. Results of Tests.

Hammer	Mass of Sphere m_2	Mass of Hammer	Mass of Hammer and Support m_1	α in Deg.	β in Deg.	θ in Deg.	ω in Deg.	ε from Eq. 1	K. E. Loss from Eq. 2
No. 1.....	232.9	659.0	782.3	2.97	6.63	11.0	15.9	.9405	2.64
No. 2.....	232.9	518.8	634.1	3.27	6.29	11.5	15.2	.8981	5.19
No. 3.....	232.9	332.6	455.9	3.00	5.71	13.0	15.5	.8406	9.92
No. 4.....	232.9	245.6	368.9	3.02	5.95	15.0	15.2	.6829	20.46
R. R. No. 1....	548.0	4,425.0	4,770.0	2.20	12.30	15.1	24.3	.8200	3.40
R. R. No. 22...	548.0	4,440.0	4,785.0	2.20	12.20	15.1	25.2	.8730	2.25
R. R. No. 3....	548.0	4,320.0	4,665.0	2.10	12.00	15.0	24.8	.8640	2.26
R. R. No. 20...	548.0	2,780.0	3,125.0	1.40	11.10	15.0	22.6	.7600	6.30
R. R. No. 22...	548.0	2,752.0	3,097.0	1.40	11.10	15.0	22.9	.7800	5.80

Note:—Hammers 1, 2, 3 and 4 are from the table published in 1918. These results are included for comparison. Hammers 1 and 2 are high grade mechanic's hammers. Hammer 4 is one purchased at a five and ten cent store.

It is of interest to note the superior quality of railroad hammers numbers 22 and 23. I have tested quite a number of different kinds of hammers and my students have also tested different types. These two hammers stand at the head of the list in energy conservation.

Appreciative acknowledgment is hereby given to my former student, Dr. Robert L. Petry, who assisted in the experimental work upon these hammers.

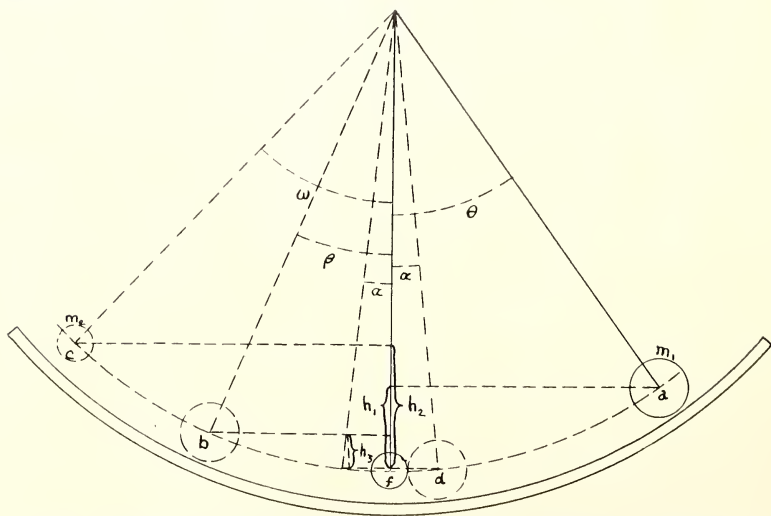


Fig. 2—Diagram used in deriving equation for the coefficient of restitution and the percentage loss of kinetic energy.

SCATTERING OF LIGHT BY SMALL PARTICLES.

EDWIN MORRISON, Michigan State College.

According to the theory of scattering of light by small particles "if a beam of light is passed through a transparent medium containing in suspension small particles, the refractive index of which differs from that of the surrounding medium, light will be given off by the particles in all directions. If the particles are very small, the color of the scattered light is blue, and it is more or less completely plane polarized, the direction of vibration being perpendicular to the direction of the incident beam. If the incident beam is plane polarized to start with no light is scattered by the cloud of particles in directions parallel to that of the incident vibration." For a continuation of this discussion see Wood's Physical Optics, page 624, from which the above is quoted.

I wish to submit the following as an interesting and simple verification of the theory of scattering of polarized light by small particles which to my knowledge has not been published.

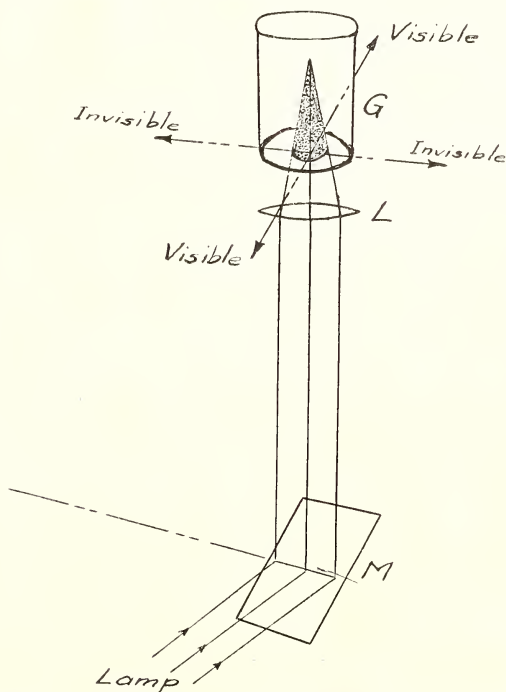


Fig. 1.—Diagram of apparatus used to demonstrate the theory of scattering of polarized light by small particles.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

Set the reflecting glass of a Norrenberg polariscope so that it makes an angle of 33° (the polarizing angle) with the vertical axis. Then locate an arc lamp at such a position that direct rays from it will be reflected vertically upward from the glass reflector along the axis of the polariscope. Place a large flat-bottomed beaker (or any flat-bottomed glass vessel) above the polariscope. Fill the beaker with a solution of uranium nitrate. Place beneath the beaker one of the short focus lenses of the polariscope. A luminous cone of light will be formed in the uranium nitrate solution which will be visible from a side position at right angles to the plane of vibration of the polarized light, and almost invisible from a side position in the plane of the vibrations of the polarized light. See figure 1. The same effect is manifest when a solution of iron chloride in water is used instead of the uranium nitrate. Any solution containing very small particles in suspension will act in like manner, though perhaps not with the same brilliance as that of uranium nitrate.

The experiment can be varied by substituting for the lens a diaphragm with a round opening. In this case a cylindrical beam of light will appear in the solution which will be visible from one direction and invisible from a position at right angles to it.

The experiment can be further varied by using a Nicol prism instead of the reflecting glass of the polariscope as a source of polarized light.

The following precautions may be noted. The experiment must be carried on in a dark room and stray light from the lamp must be avoided. In case a diaphragm is used it will produce a certain small amount of diffused light which prevents entire extinction of light in the invisible directions. The plane where the cone of light from the lens enters the beaker may also act to produce a small amount of diffused light which prevents entire extinction of light in the plane of vibration of the polarized beam. These effects can usually be screened off.

SOME OBSERVATIONS ON THE PROPERTIES OF CERTAIN SO-CALLED THERMAL INSULATORS.

JOHN B. DUTCHER, Indiana University.

It is often necessary in laboratory practice to employ some thermal insulating material as covering for vessels to prevent excessive loss of heat when it is desirable to maintain the contents at a fairly constant temperature.

Many common substances, such as paper, cotton felt, wool felt, wood pulp, and asbestos, are useful for this purpose. One of the most frequently used materials is asbestos in some form, such as fiber, sheet or

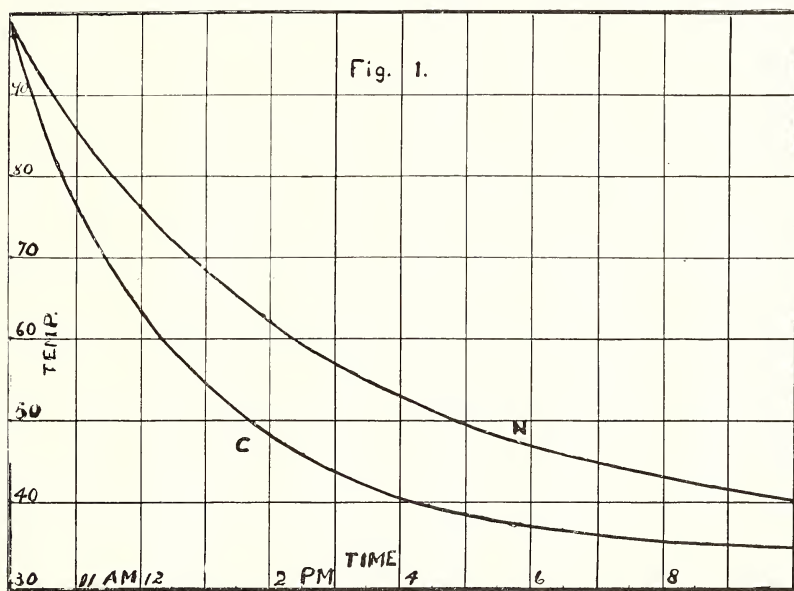


Fig. 1—Diagram of time and temperature results plotted from results reported in Table I.

paper. Asbestos paper is thin sheet, quite flexible and may be applied to a surface in one or more layers with little trouble. Merely wetting the sheet and applying it to a surface, like wallpaper, gives without use of any paste a fairly permanently adhesive coating, provided the surface is hot.

The object of these observations was to determine the effect of putting a layer of this paper on the exposed surfaces of vessels containing hot liquids or gases. Two sections of fairly bright tin downspouting, each four inches in diameter and 24 inches long, were fitted

with bottoms and covers. These were set about 12 inches apart in a basement room and protected from drafts. Each vessel was filled with the same mass of boiling water. The water was stirred and the temperatures noted at frequent intervals until the temperature of each was nearing that of the room, which did not vary more than one and one-half degrees throughout the entire time. As the vessels and their contents cooled the difference in the temperatures of the two at no time was greater than 1.25° and most of the time the thermometers read practically the same.

TABLE I.—Temperature Records of Covered and Uncovered Vessels.

Time	Temp. Room	Temp. C (covered)	Temp. N (uncovered)	Excess
10:00	26	99.1	99	—0.1
11:00	26.5	76.2	85.3	9.1
12:00	27	63	75.7	12.7
1:00	27.1	54.6	68.1	13.5
2:30	26.5	45.8	59.2	13.4
3:00	26.1	43.9	56.8	12.8
4:00	26.3	41	53	12
6:00	27	37	46.9	9.9
8:00	27.5	35.1	43	7.9

One vessel (N) was left naked and the other (C) was covered with a single layer of the asbestos paper. When the covering was thoroughly dry the vessels were again filled with hot water and allowed to cool as before. The water in each was continually stirred and temperatures taken at stated intervals. Table I shows some of the readings obtained and figure 1 shows the result of plotting time and temperatures. These are merely the ordinary cooling curves and show the temperature of each at any time during the cooling process.

A pair of much larger vessels were tested in the same manner. Table II, made up of readings selected at random from a very large list taken during the cooling of the covered (C) and naked (N) vessels, will show the results.

Each of the pair of smaller vessels was equipped with a heating coil of nichrome wire. These coils had the same resistance, and when

TABLE II.—Temperature Records of Covered and Uncovered Vessels

Time	Temp. Room	Temp. C (covered)	Temp. N (uncovered)	Excess
11:52	24	99.5	99.6	.1
12:41	24	91.2	92.3	1.1
1:05	23.3	84	88.3	4.3
1:45	24	77.5	83.2	5.7
2:45	24	69	76.5	7.5
3:15	24.1	66	74	8
4:00	24	61.1	69.8	8.7
4:42	23.8	55	66.2	11.2
5:22	24	53.8	63	9.2

Size of vessels, Diameter = 7.35 in., Length = 38.6 in.

connected in series would have the same current and therefore the same quantity of heat generated in each vessel.

By trial a current value was found which would maintain the naked vessel filled with water at 85° to 86° C. in a room whose temperature was 27° C. This equilibrium could be maintained for an hour. The covered vessel, in the meantime, maintained an equilibrium at a temperature of but 77° C. The water in both vessels was stirred at regular intervals and precaution was taken to prevent escape of vapor.

An effort was then made to find the respective currents required to maintain each vessel at the same temperature and in equilibrium in a room whose temperature was maintained at 27° C. A common temperature of 79° to 80° C. was maintained in each for more than 90 minutes. To do this required a current of 7.2 amperes in the coil of the naked vessel, while 8.1 amperes were required for the other. Since the heat developed by each coil is proportional to the square of the current in it, we see that over 24 per cent more heat was required to maintain the covered vessel at the given temperature than was required for the naked one.

Two sections of furnace pipe used to convey hot air were obtained. These were made of bright tin and were six feet long and nine inches in diameter. The ends were closed and all seams and joints were made tight. Each was equipped with a heating coil of nichrome wire which extended nearly the full length of the pipe parallel to but somewhat below the central axis when the pipe was placed in a horizontal position. One-half inch holes were drilled through the wall of each pipe in various places and a short section of three-fourths inch thin brass tube was soldered around each. Corks were placed in each small tube through which thermometers were inserted so the bulbs extended one inch inside the wall of the large tin pipes.

The coils were connected in series, as in previous cases, and a current of electricity was passed through and regulated so as to bring the temperature of the air within the large pipe to approximately 150° C. in a room whose temperature remained between 26° C. and 27.5° C. Exchanging heating coils or exchanging positions of the tubes made practically no difference in the temperature maintained by the given current. One of the pipes was then covered with one layer of commercial asbestos paper and after thorough drying the tests were repeated, using the same current, with results as shown in Table III.

TABLE III.—Temperature Records of Covered and Uncovered Vessels.

Temp. Room	Temp. Covered	Temp. Uncovered	Excess
27.5	121°	156°	35
*26.	118°	152°	34
26.	120°	152°	32
26.1	118°	152°	34
26.	118°	154°	36
†26.4	122°	155°	33

* Exchanged positions of vessels.

† Exchanged heating coils.

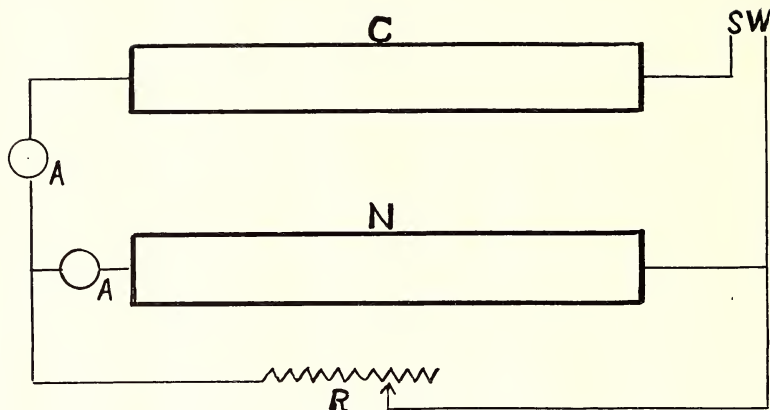


Fig. 2—Diagram of apparatus used in insulation tests.

An arrangement was made as shown in figure 2 which made it possible by trial to obtain a current in each coil of such a value that the naked pipe N and the covered pipe C were kept at the same temperature, 145° C. to 146° C. in a room whose temperature ranged from 27° C. to 28.5° C.

As the coils were no longer carrying the same current and consequently were themselves at quite different temperature, their difference in resistance had to be taken into consideration. The current and the potential drop in each coil was measured and from these data the energy developed per second in each pipe could be calculated.

The temperatures inside the pipes were maintained for at least one hour in each test and were determined by the average of the readings of five similar thermometers inserted at intervals along each pipe. When a steady state was reached the five thermometers in the same pipe did not differ among themselves more than 1.5° C. at any time.

A temperature of 140° (approximately 300° F.) was maintained in each pipe and the necessary current and potential drop in each coil noted, from which the heat energy developed in each was computed. These results appear in Table IV.

TABLE IV.—Temperature Records and Energy Required to Maintain a Temperature of 140° C.

Time	Temp. Room	Temp. (C)	Temp. (N)	Amperes		Volts	
		Covered	Uncovered	C	N	C	N
7:30	27.5	144.	142.	10.3	8.2	62.	50.2
8:30	28.	141.	141.5	10.15	8.2	61.	50.2
9:00	28.	140.	141.	10.	8.25	60.	50.3
9:30	28.2	140.5	140.	10.1	8.2	60.2	50.3

Input in watts C=60.22; N=41.25.

Covered pipe requires nearly 45% more energy to maintain a temperature of 140° C. than does the naked one.

That a *thin* layer of some poor conducting material applied to a polished surface increases the rate of loss of heat from that surface is a well known fact. The increased radiation resulting from the profound change in the nature of the exposed surface frequently outweighs the insulating effect. The covering of many smooth, bright and even polished surfaces of vessels, and especially of hot-air furnace pipes, with a thin layer (usually a single thickness) of asbestos paper in response to the popular notion that it prevents the escape of heat, appears to be a mistaken procedure. Its use as a covering for hot-air pipes must be justified on some other grounds.

It has not been the purpose of this paper to quote exact quantitative results. Work is in progress now which will yield quantitative losses from various surfaces under conditions experienced in actual practice. This work will form the basis of another paper to be published soon.

SOME PROPERTIES OF PIN HOLE SOUND PROBES.

JAMES E. BROCK, Purdue University.

Dvorak¹ observed that a violent wind issued from the mouth of a conical tube placed in front of the open end of a sounding Kundt tube, if the conical tube were of such dimensions as to resonate to the frequency of the sounding tube. He also observed that smoke particles were driven violently from the sounding box of a tuning fork when the fork was strongly stroked; and that in a Kundt tube in which standing waves of sound were maintained there was a steady flow of air out of the tube along the axis and into the tube adjacent to the walls. At the same time Dvorak showed from theoretical reasons that the average pressure at a node could not be zero, except for waves of infinitesimal amplitude, nor could the pressure be zero at an anti-node; hence the steady flow along the axis. Rayleigh and Dvorak made observations along the axis of the tube by probing with an open tube attached to a sensitive manometer. Barus² found that if the orifices in the probes were conical and of the right dimensions the pressure phenomena were reversible: i.e., if a salient orifice gave reduced pressure readings on the manometer the re-entrant orifice gave increased pressure readings at the same point along the standing wave. Dvorak observed that the response of the conical hood was best when in resonance and Barus suggests the same thing for the length of the probing tube in his work.

We shall distinguish our conical orifices by designating them salient and re-entrant in the usual sense in which the terms are used in hydrodynamics. The salient orifice normally gave an indication of reduced pressure and the re-entrant orifice gave increased pressure indications.

My first observations on the phenomenon were made with an organ pipe for a source of sound into which a considerable wad of cotton had been introduced about 15 cm. in front of the vibrating jet to damp out any steady flow of air down the pipe. Shellac was used to stick a paper hood over the end of an 8 mm. glass tube about one meter long and a hole was punched in the hood with a common pin (re-entrant orifice). This probe showed an increase in pressure above atmospheric pressure at the node of about 2 mm. of water when the organ pipe (384) was blown vigorously. The depression of pressure was about the same when the hole was made salient. The manner of variation of pressure on the manometer with distance the probe advanced into the tube is shown in figure 1. Similar curves have been secured by Barus.³ As was to

¹ Weid. Ann. 3, 328 (1878).

² Carnegie Inst. Pub. 310, 26 (1921).

³ Carnegie Inst. Pub. 310, p. 25, 26 (1921).

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

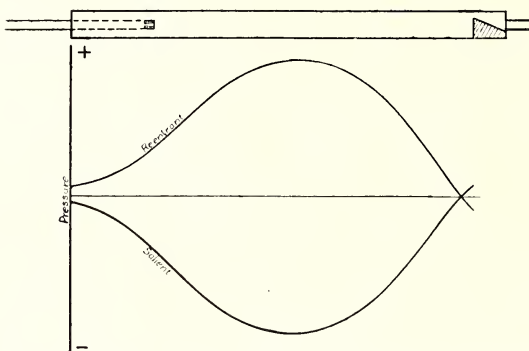


Fig. 1—Variation of pressure on manometer with distance the probe advanced into the tube.

Fig. 1—Variation of pressure on manometer with distance the probe advanced into the tube.

be expected from theory, the probe showed increased pressure at nodes and apparently zero pressure at anti-nodes, while in the region immediately about the lip of the pipe there was considerable indication of negative pressure difference for the re-entrant vent. Later observations about the lip of an organ pipe shows the pressure conditions in the region to be very unstable, any change of position of objects in the neighborhood or slight changes in the pressure of the source alters the whole pressure topography about the lip without sensibly altering the positions of the nodes in the pipe.

Experiments were made to adapt various displacement bubble gauges for measuring the pressure differences. The general form of such a gauge is shown in figure 2. Two large reservoirs were sealed on to a



Fig. 2—Displacement bubble gauge for measuring pressure differences.

capillary and a bubble of air about 2.5 cm. long was trapped in the capillary as shown. The displacement of the bubble is proportional to the difference in pressure. The amount of displacement is determined by the amount of liquid exchanged in the reservoirs; i.e., proportional to the area of cross-section of the reservoirs and capillary. In one case this ratio was made 100 to 1, which meant that a change in level of one millimeter of water in the reservoir would produce 100 millimeters dis-

placement of the bubble. Using gasoline for the fluid in the gauge, a displacement of one millimeter of the bubble corresponded to a difference in pressure of 0.46 dynes. The gauge is easily set up and is sufficiently sensitive to show the phenomenon when an organ pipe is blown just above a whisper. The one objection to this type of manometer is its sluggish response, it sometimes requiring as much as ten minutes to come to a full reading. It was at first thought this sluggishness could be partly attributed to the fact that the pressure differences at the orifice were not set up instantly, but later experiments with smoke particles indicated that the pressure differences were practically established with the first oscillation of the sound wave and the time lag of pressure differences at the orifice is really very short indeed. The sluggish behavior of the instrument, then, must be due to the properties of the liquid in the manometer.

Pressure gauges with a stretched membrane were also used successfully to record the pressure differences. The construction of such a gauge is shown in plan in figure 3. D was a sheet of "dental dam"

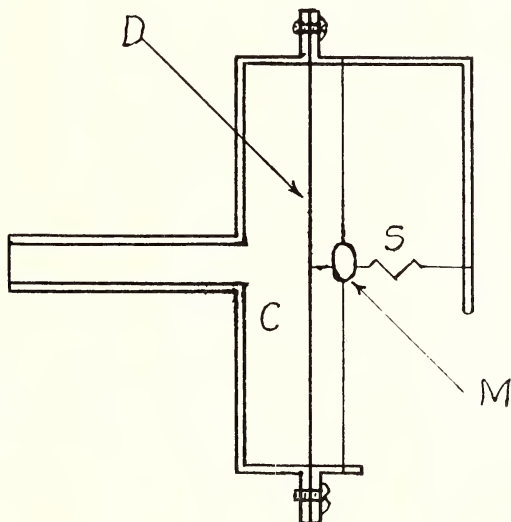


Fig. 3—Plan of pressure gauge with a stretched membrane.

stretched taut over a cavity C about one centimeter deep and five centimeters in diameter. M was a small mirror mounted on a pinion and had one edge attached to the center of the membrane with a silk thread so that it rotated with the inflation and deflation of the gauge. S is the hair spring from a watch to hold the silk thread taut. The deflections were read with a telescope and scale or by observing the spot of light reflected from the mirror. The gauge was very sensitive and quick in its response. An objection to the instrument was that the displaced image of the scale was not distinct. Later experiments with the manometric

flame showed this indistinctness of the image to be due to an oscillatory pressure which is superimposed upon the steady pressure trapped by the probe. The steady pressure difference is due to a difference in conductivity in the two directions through the conical orifice. The superimposed oscillatory pressure is not observed on the liquid gauges due to the inertia of the liquids.

The first orifices used to study the phenomenon were made by punching holes in paper hoods cemented to the end of glass rods or by drawing glass tubes to pin-hole orifices. Most of the orifices used were made by drilling holes in small brass plugs with a number 60 drill. A conical orifice was readily made by broaching out this hole with a tapering reamer made by flattening the sides of a phonograph needle or a

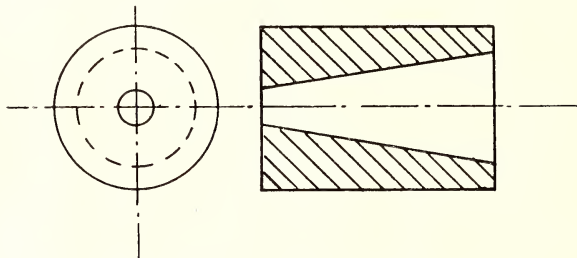


Fig. 4—Plan of the orifice in probing tube.

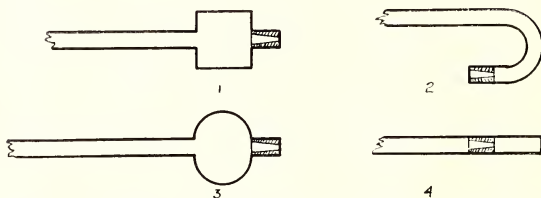


Fig. 5—Shapes of probing tubes examined to determine the influence of shape on the pressure trapped.

short length of small steel rod. Seemingly any hole of the approximate diameter of 0.2 to 0.4 mm. traps energy from standing waves in air; and the amount of energy trapped is but little affected by the character of the edge of the hole, the length of the hole up to about 8 mm. of length, or the angle of the conical orifice for angles less than about 20° . In fact the amount of energy trapped by an orifice that exhibits reversibility seems to depend only on the amount of energy possessed by the wave at the point. Increasing the angle of the orifice to about 30° makes the orifice behave as though it were cylindrical. The plan of an orifice is shown in figure 4. Experiments were performed to test the influence of the region immediately behind the orifice upon the response but no shape or dimension comparable to the orifice seemed to have any effect. A few of the shapes examined are shown in figure 5. A hood over the orifice as shown in figure 5 affected the emission of smoke particles from the orifice but didn't affect the pressure response.

For sources of sound, organ pipes and telephone receivers, or loud speaker units, were used. The organ pipe used most had a frequency of 384 cycles when blown at a pressure of 25 cm. of water. The radio loud speaker unit attached to a Kundt tube is the most convenient method for securing standing waves and the frequency may be varied over wide ranges if the tube is arranged for tuning. The loud speaker unit may be excited by a vacuum tube circuit or a high frequency generator.

Salient Vent. The orifice was placed in the end of the probing tube and advanced along the axis of the Kundt tube in the manner suggested in figure 1. With the end of the probing tube not containing the orifice attached to the manometer the pressure reading was below atmospheric as the orifice approached a nodal point in the Kundt tube. The pressure difference approached zero as the orifice was brought near to an anti-node, but normally did not come to zero reading at the anti-node. If smoke particles were introduced into the probing tube before it was attached to the manometer, the smoke column appeared to be driven back from the orifice about 3 cm. and come to rest. The displacement of the smoke column seemed to take place with the first cycle of the sound wave striking the orifice and no particles were seen to be drawn out into the Kundt tube through the orifice nor were any seen to be driven back into the manometer from the probing tube. The magnitude of the pressure differences and the behavior of the smoke particles was independent of the dimensions of the probing tube. If dust or smoke particles were introduced into the Kundt tube immediately in front of the orifice, they were violently disturbed and the wind seems to have its origin at the probe; i.e., there was a violent wind from the orifice into the Kundt tube. The wind issuing into the Kundt tube was stream-line for more than 10 cm. while the disturbance immediately behind the orifice was turbulent. The violent wind which issued from the vent explains the reduced pressure observed on the manometer. The disturbance both inside and outside the probing tube was greatest when the probe was at a nodal point in the Kundt tube. If the rubber tube connecting the manometer to the probe was disconnected the smoke particles issued slowly from the open end of the probe opposite that containing the orifice. No evidence of standing waves was observed in the probing tube for any frequency of blowing the Kundt tube or for any length or size of the probing tube. If standing waves were set up in the probing tube they were too feeble to disturb the lightest dust particles. When the probe was attached to a Koenig flame the usual serrated image was secured on the revolving mirror showing that pressure trapped by the orifice was not steady. Apparently a difference of pressure was established and super-imposed on this was a lesser oscillatory pressure difference. The same thing was suggested by the blurred image on the diaphragm gauge.

Re-entrant Vent. The salient orifice of the preceding paragraph was removed from the probing tube and reversed to form the re-entrant orifice. Reversing the orifice reversed most of the phenomena observed of the salient orifice. The re-entrant orifice gave increased pressure

indications on the manometer where the salient orifice gave reduced pressure readings. If smoke particles were introduced into the probing tube before it was attached to the manometer, with the first start of the standing wave about 4 cm. of the smoke column was jerked violently out of the probe through the orifice into the Kundt tube, but only this initial puff was observed so long as the probe was attached to the manometer. When the probe was not attached to the manometer there appeared to be a steady stream of smoke particles issuing from the orifice into the Kundt tube so long as any smoke remained in the probing tube and the motion was stream line for about 10-15 cm. before the velocity was reduced and the motion became turbulent. While this jet of smoke particles was issuing from the vent a violent disturbance of the smoke particles in the probing tube was noticed just back of the orifice which was always turbulent. A pile of dust particles in the Kundt tube immediately in front of the orifice had a channel blown through it by the jet of air issuing from the vent. Closing the end of the probing tube opposite to that containing the orifice with the finger stopped the flow of smoke particles from the probe, but dust particles in the Kundt tube were still disturbed by a wind that had its origin at the vent. Attaching the probe to the Koenig flame gave the serrated image just as in the case of the salient orifice, and the displaced image on the diaphragm gauge was blurred.

Cylindrical Vent. Probes with cylindrical vents show always an increased pressure difference on the manometer at nodal points in the Kundt tube. They do not exhibit the phenomenon of reversibility. There was a faint wind from the orifice into the Kundt tube when the end not containing the orifice was closed with the finger or attached to the gauge, but smoke particles introduced into the probe were not drawn through the orifice into the Kundt tube by the pressure trapped. The displacement indicated by the diaphragm gauge was for increased pressure difference and the image was blurred. Probes without orifices of any kind responded, in so far as pressure was concerned, in the same manner as cylindrical vents. No wind was observed to be set up from the end of the probe for any condition of blowing the Kundt tube, but dust particles introduced into the probing tube show nodes and loops as in the larger Kundt tube.

In conclusion, the writer wishes to express his appreciation of the interest shown in the problem and the valuable suggestions given by Dr. A. L. Foley, of Indiana University, under whose direction this investigation was undertaken.

A CALORIMETRIC DETERMINATION OF CORE LOSSES IN HIGH FREQUENCY TRANSFORMERS.

B. A. HOWLETT, Rose Polytechnic Institute.

The data reported below were obtained by Ernest O. Johnson, B. S. in E. E., '27, Rose Polytechnic Institute, while making a study of multiple stage radio frequency amplification.

The method used for the determination of the iron loss is essentially that previously reported by Prof. R. R. Ramsey for the measurement of condenser losses. The iron sample was placed in a one-half by six-inch test tube which in turn was sealed into a three-quarter by eight-inch test tube. A bent glass tube connected the inner test tube with a similar calorimeter containing a heating element. Each tube connection was sealed with a mercury seal. A short column of water in the connecting tube served as a pressure indicator.

The calorimeter containing the iron sample was placed inside a heavy coil of three and one-half turns. A heavy high frequency current was passed around this coil and the test sample was heated by the eddy currents set up in it. This rise in temperature expanded the air in the inner test tube and forced the water column to the right. Current from a storage battery was then passed through the heating element in the second test tube until equilibrium was restored. In most cases conditions became constant after 30 minutes of operation, and the observations were continued for a second 30 minutes. The power supplied to the heating element in the second test tube was very carefully determined and under conditions of equilibrium should be an accurate measure of the iron loss. Figure 1 is a photograph of the complete apparatus.

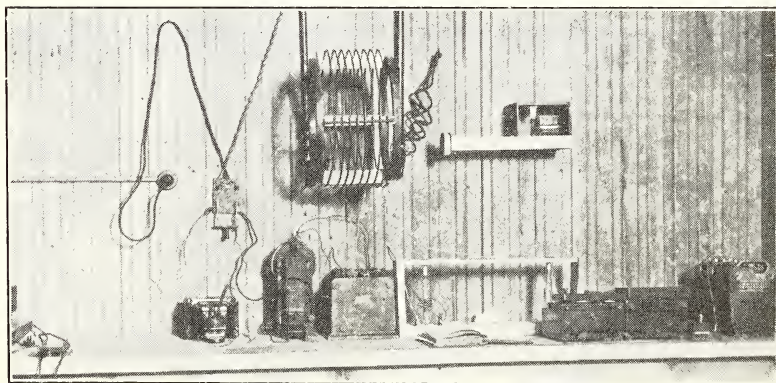


Fig. 1—Complete apparatus used in calorimetric determinations.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

Three core materials were tested. The first was made from commercial power transformer laminations of silicon steel .017 inches in thickness. The second was a core prepared from steel taken from a well known radio transformer with laminations of .004 inches in thickness. The third sample was prepared by molding together fine filings of the second steel with a binder of paraffin and rosin. A power hack saw was used to produce the filings. The results of the tests showed losses as follows: Silicon steel .017 inches in thickness gave 4.570 watts loss per cubic centimeter or .290 watts loss per gram; radio transformer steel .004 inches in thickness gave 3.702 watts loss per cubic centimeter or .225 watts per gram; ground transformer steel .394 watts loss per cubic centimeter or .049 watts loss per gram. These comparative results were all taken with a constant power input to the high frequency circuit. The frequency of the exciting circuit was 603 kilocycles and was thus inside the longer wave length broadcasting band.

A radio frequency transformer was built with a removable core and placed in the circuit of a radio frequency amplifier. Resonance curves were plotted using both cores two and three with a constant input to the circuit. These curves showed the maximum ordinate of the resonance curve for the laminated steel to be only 11.66 per cent of that for the ground steel. This compares very favorably with the ratio of the losses which was 10.62 per cent for equal volumes. Cutting down the iron losses thus very greatly increases the efficiencies of these transformers.

A MAGNETIC METHOD FOR THE DETERMINATION OF THE ELASTIC LIMIT OF IRON AND STEEL.

B. A. HOWLETT, Rose Polytechnic Institute.

This report is a summary of a portion of the thesis work done by Victor E. Schlossberg, B. S. in E. E., '26, and Paul E. Duffendach, B. S. in C. E., '27, at the Rose Polytechnic Institute.

While studying the elongation of a sample of steel due to its magnetization, Mr. Schlossberg investigated the effect of applying a tensile stress to the sample while it was subjected to a fairly strong magnetic field. The sample, a 1½-inch cylindrical steel bar, was placed in a 100-ton Olsen testing machine which could be run at a very uniform speed. Two primary coils supplied with constant current from a 32-volt storage battery gave the required magnetomotive force while a secondary coil, placed between the two primary coils and connected through a damping resistance to a ballistic galvanometer, served to indicate any change in flux due to the stress applied. A strain gauge was also attached to the sample to indicate the elongation.

Considerable care was taken to shield the apparatus from stray fields which might mask the effect to be studied. With this arrangement, a uniform change in flux would produce a correspondingly uniform deflection of the galvanometer. With the testing machine running

at constant speed, stress, strain gauge, and galvanometer readings were taken every ten seconds. These readings were plotted in two curves, stress against strain and stress against galvanometer deflection.

The samples of steel and wrought iron showed the usual abrupt change in the stress-strain curves at the yield point. The stress-galvanometer deflection curves showed a slight progressive increase in flux for stresses up to approximately half of that at the yield point. For stresses approaching the yield point from this value the rate of increase of flux became much more rapid till the deflection reached a sharp maximum point at about 400 pounds per square inch before the yield point. From this point the increase in flux rapidly diminishes to zero and a decrease in flux begins, giving a reversal of the galvanometer reading at, or very close to, the yield point. A series of tests on different samples of the same steel and iron, with the machine run at different speeds show curves of the same general form and with the point of maximum deflection occurring consistently within two or three hundred pounds of the same stress. This maximum point evidently indicates rather sharply the true elastic limit and the intercept on the stress axis, the yield point.

Figure 1 shows a typical set of curves for a mild steel while figure 2 shows the same for wrought iron. Strain gauge readings were plotted directly and the stress is given in pounds per square inch.

Mr. Duffendach applied this method to the more difficult task of determining the elastic limit for malleable cast iron. The samples were furnished the Department of Civil Engineering by the National Malleable and Steel Casting Company of Cleveland for this investiga-

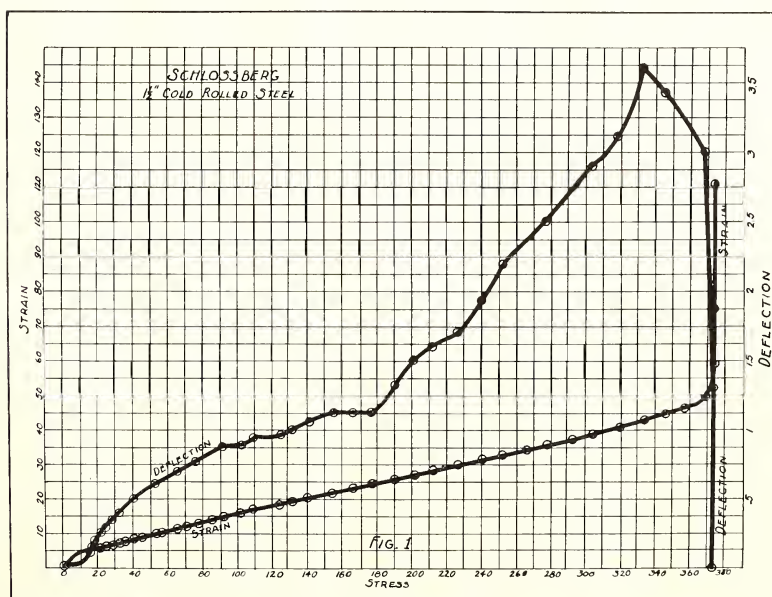


Fig. 1—Stress-Strain and Stress-Deflection curves for mild steel.

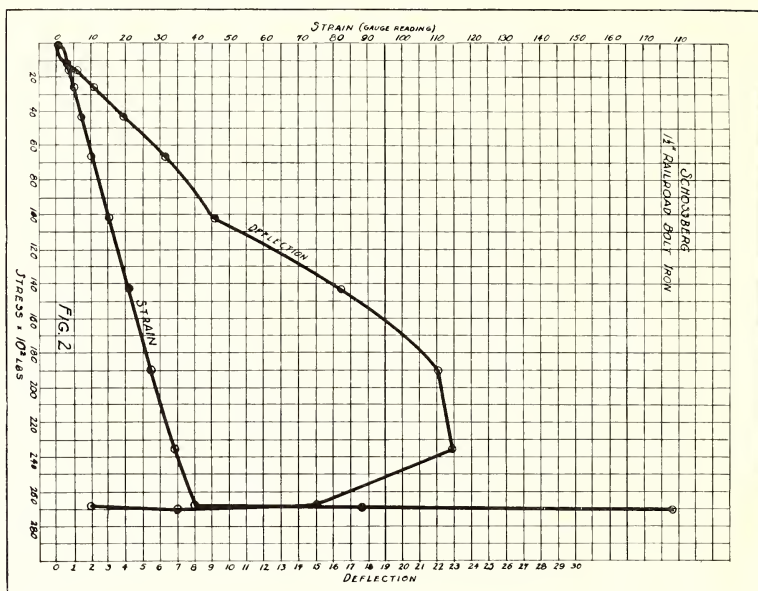


Fig. 2—Stress-Strain and Stress-Deflection curves for wrought iron.

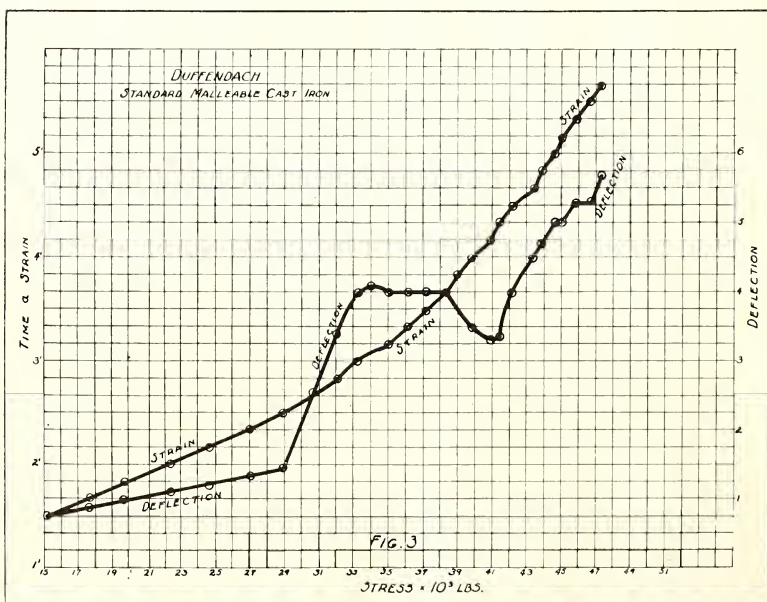


Fig. 3—Stress-Strain and Stress-Deflection curves for malleable cast iron.

tion. They were standard test castings with only about four inches of uniform cross section. This is necessary to prevent flaws in casting. As a result it was not possible to use a strain gauge after the coils were in place. Preliminary tests showed a linear relation between time and elongation when the machine was run at constant speed. The readings were taken as before and the time plotted against stress to determine the shape of the stress-strain curve. For this kind of material the flux changes were much smaller so the number of turns on the secondary coil was increased and less resistance used in series with the galvanometer.

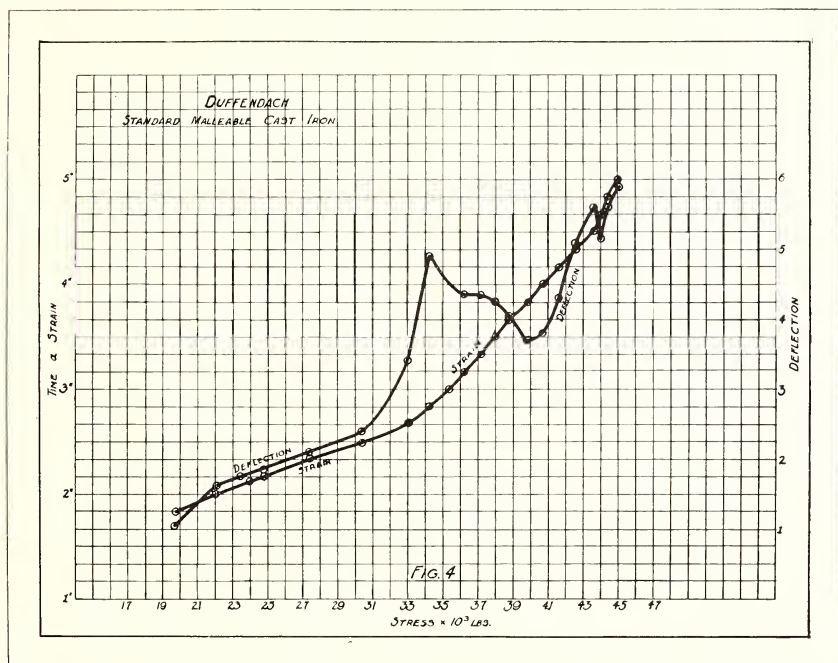


Fig. 4—Stress-Strain and Stress-Deflection curves for machined malleable cast iron.

Figure 3 shows a typical set of curves for the malleable cast iron. Figure 4 shows a set of curves for another sample which has had the surface machined away. The machining, which removed the outer skin of the casting, has produced little effect on the curves.

As expected, the stress-strain curves showed a gradual curvature which made it difficult to determine either the elastic limit or the yield point from them. The stress-deflection curves, however, showed much the same preliminary shapes with definite and consistent peaks for the elastic limit. After this point the curves differed widely from those for wrought iron and steel. The stress-strain curves showed no definite yield point with large slippage and this was confirmed by the deflection curve. After the initial drop in galvanometer deflection

following the peak point, successive peak values were shown corresponding to successive slippage and resetting. These changes occurred so rapidly that no actual reversal of the galvanometer reading was obtained.

The most consistent point on the deflection curve is the first peak point. For all the runs taken this point occurs within about 200 pounds either side of 34,200 pounds per square inch. From the curves shown it can be seen that the stress-strain curves show considerable curvature before this is reached. In spite of this, the consistency of the stress values at this peak point and its obvious interpretation from the wrought iron and steel curves make it the logical value to interpret as the elastic limit. This value can also be much more definitely located than any corresponding point on the stress-strain curve for this material.

THE ROLE OF VALENCE AND ELECTRONS IN THE
TEACHING OF GENERAL CHEMISTRY.

W. M. BLANCHARD, DePauw University.

In the history of every science there comes from time to time some epochal discovery or some novel interpretation of phenomena that marks the beginning of a new era. The development of chemistry has been particularly marked by these epochal discoveries and unfoldings of new ideas, many of them, it is only fair to say, having had their birth in the sister science of physics.

Priestley discovers or, more accurately, rediscovers oxygen, and soon Lavoisier sweeps away the old phlogiston theory and sets the new science upon solid foundations. Dalton pierces the hazy dreams of ancient philosophers and visions for the chemical world a practical theory of atoms,—and again the infant science moves a step forward. Davy finds an effective tool in the newly discovered galvanic current, splits asunder the hitherto resistant alkalis, and opens the way for Berzelius's theory of dualism, an electrochemical theory that dominated the minds of chemists for more than a quarter of a century. Wöhler's synthesis of urea marked the beginning of another epoch and for another quarter of a century the open sesame in every chemical laboratory of Europe was synthetic chemistry. Kekulé's linking of atoms and the benzene ring led to the innumerable novelties of structural chemistry and maintained the chemist's enthusiasm at fever heat for some decades longer. Suddenly Arrhenius stepped into the limelight with his theory of ionization in salt solutions and from that time down to very recent years chemistry has fairly leaped forward under the magic power of ions. Radioactivity, cathode rays, and the electronic conception of atoms, discovered and fashioned for the most part in the workshop of the physicist, have been of incalculable value in extending the domains of chemistry in our own day.

It is the purpose of this paper to attempt to add a little impetus to the present tendency to interpret the reactions of general chemistry in the light of the newer ideas of atoms and electrons, coupled up with the older inadequate conceptions of valence, as we endeavor to introduce students to an increasingly popular and practical science.

For many years it has been quite the common custom to classify chemical reactions, more accurately chemical action, from a material standpoint under six heads: combination, decomposition, double decomposition, displacement, substitution, and internal rearrangement, the last two finding a prominent place in organic chemistry. Double decomposition reactions have been explained for some time on the basis of the law of mass action and ion product constant. We now have a

single viewpoint from which to interpret the other three classes of chemical action and we need no longer regard them as individual types. They are simply valence changes and a valence change merely involves the transfer of one or more electrons from one atom to another. This involves the conception of positive and negative valence and of course the idea of neutral valence, also designated as zero valence.

Four simple assumptions, which we may no longer regard as assumptions but as well-established facts, form the basis of these interpretations:

1. Each element in the uncombined state has a valence of zero.
2. Hydrogen in combination has a positive valence of one; that is to say, each hydrogen atom in entering into combination with some other atom has lost one electron.
3. Oxygen in combination has a negative valence of two, which means that in entering into combination with some other element each oxygen atom has gained two electrons. In peroxides, however, we must assume for oxygen a negative valence of one.
4. In every compound there is a neutrality of valence; in other words, an exact balance between the total positive and negative electrical forces in the molecule of the compound.

With the exception of double decomposition reactions, chemical action in general may now be interpreted as merely an oxidation-reduction process, oxidation taking place where an atom is losing electrons, reduction where an atom is receiving electrons. Obviously there cannot be one without the other.

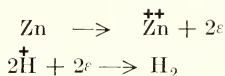
The modern theory of the atom and the further light thrown upon the Periodic Law by the derivation of Atomic Numbers give us a rational explanation of why the maximum change in the valence of any element should be eight. In some elements the tendency to lose electrons is greater than the tendency to acquire them; in others the tendency to acquire electrons is greater than the tendency to lose them; while in still others the tendency in either direction appears to be more nearly equalized.

Chlorine, of the seventh group of the periodic system, for example, shows a marked tendency to acquire one electron although under proper conditions it may lose one, three, five, or seven, the total range being eight. Sulphur, of the sixth group, may gain two electrons but on the other hand it may lose two, four, or six, the total range being eight. Nitrogen, of the fifth group, may receive three electrons or lose two, three, four, or five, the total range once more being eight. Carbon, of the fourth group, may gain four or lose two or four; again the range is eight. Boron, of the third group, may lose three but may not acquire any, unless possibly it be three in boron nitride. Beryllium, of the second group, may lose two but not receive any; the same is true of magnesium, cadmium, zinc, and others. Copper, of the first group, may lose one or two but acquire none, while gold may give up one or three but gain none. Lithium and the other alkali metals may lose only one and receive none. Note exceptions in metallic hydrides.

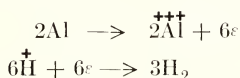
With this idea in mind, therefore, that chemical action is primarily

an electronic transfer, this transfer affecting only two elements in the interacting substances, or in the single substance if it is what is ordinarily called decomposition, let us examine several common reactions and note how they illustrate the principle that has been stated.

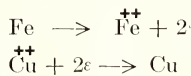
The typical reaction between an acid and a metal, zinc and sulphuric acid for example:



Or aluminium reacting with hydrochloric acid:

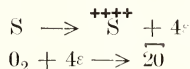


Or the displacing of a metal in a salt by another metal:



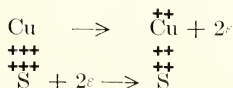
Here zinc, aluminium, and iron are oxidized while hydrogen and copper or, to speak more accurately, hydron and cupron are reduced.

Let us consider another example, the preparation of sulphur dioxide. We may readily prepare the gas by two methods; by the combustion of sulphur in air or oxygen, or by what is commonly called the reduction of sulphuric acid. In the first case we have sulphur and oxygen each with a valence of zero, the atoms of each element having their normal number of electrons. But at the proper temperature there is a rapid transfer of electrons from sulphur to oxygen, four from each atom of the former to two atoms of the latter, with the resultant formation of sulphur dioxide.

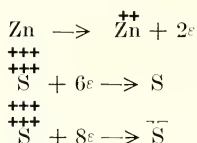


In sulphur dioxide the sulphur has a positive valence of four while the oxygen has a negative valence of two; the sulphur has been oxidized and the oxygen reduced.

In the preparation of the gas from sulphuric acid we have the opposite change so far as the sulphur is concerned. In the acid we have hexavalent sulphur, sulphur with a positive valence of six. This must be reduced to four before we can have sulphur dioxide. To make this reduction requires the presence of some element that will readily give up electrons but not with too great a facility or else the sulphur atom may be given six electrons and brought to free sulphur or even eight electrons and reduced to hydrogen sulphide. We select copper and bring the substances to the proper temperature:

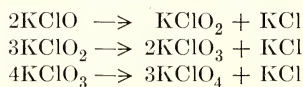


If zinc be substituted for the copper, the greater tendency of this metal to lose electrons may reduce the sulphur to its normal electronic state or even transfer to its atoms an excess of two electrons:

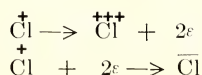


It is interesting to note that in some cases the same element may play a double rôle, some of the atoms giving electrons to or taking electrons from atoms of its own kind. An interesting illustration is afforded in the formation of the higher oxygen acids of the halogens by the process known as self-oxidation.

Even in the formation of the lowest oxygen acid of the series, hypochlorous acid for example, we have the phenomenon illustrated. As we all know, when chlorine is dissolved in water we have in solution not only molecules of chlorine but also molecules of each of the acids, hydrochloric and hypochlorous. In hydrochloric acid we find chlorine with a negative valence of one; it has gained one electron. In hypochlorous acid chlorine has a positive valence of one; the chlorine has lost one electron. In other words, in the reaction one atom of chlorine has given one electron to a second atom of chlorine, resulting in the formation of two distinct compounds of this element. When the element is run into a solution of a base, we have the corresponding salts of these acids. When the salts are heated, the valence of the halogen in some of the molecules of the oxygen acid falls as that in other molecules rises, thus yielding successively the salts of the higher acids. Potassium hypochlorite, for example, when heated yields the chlorate and at higher temperature the perchlorate. Assuming what seems fully warranted, the formation first of the chlorite, we have as ordinarily written:

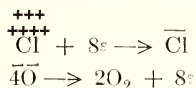


We start with a compound in which chlorine has a positive valence of one, each atom having one electron less than when it is in the uncombined state. On raising the temperature, the atom of chlorine in one molecule of the salt takes two electrons from the atom of chlorine in a second molecule and we have the formation of potassium chlorite with chlorine having a positive valence of three, and potassium chloride with this element having a negative valence of one:



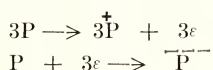
The same interesting phenomena are observed in the two other stages, the final result being positive heptavalent chlorine on the one hand and negative monovalent chlorine on the other. If the tempera-

ture is raised sufficiently, the heptavalent chlorine becomes negative monovalent chlorine with the escape of oxygen:

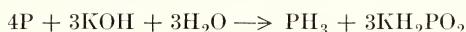


In bleaching powder, whether we accept the evidence in support of the contention that the material is a single substance and assign it the formula, CaOCl_2 , or assume that we have a mixture of hypochlorite and chloride, the conclusion is the same so far as the electronic changes in the chlorine are concerned; one atom of chlorine has given one electron to a second atom of chlorine. If we call the material calcium oxychloride and express it as CaOCl_2 , we must recognize chlorine as playing a double rôle in the molecule; one atom has a positive valence of one, the other a negative valence of one. In the upheaval arising from the treatment of this material with an acid accompanied by the liberation of chlorine, we have the reverse electronic changes; uncombined chlorine with a valence of zero is obtained.

Another interesting example of self-oxidation is presented in the formation of phosphine and potassium hypophosphite from the action of potassium hydroxide and water on phosphorus. Starting with phosphorus with a valence of zero, each atom with its normal number of electrons, we obtain two phosphorus compounds: in one the phosphorus atom has a negative valence of three, it has received three electrons; in the other compound the phosphorus atom has a positive valence of one, it has lost one electron. It is quite evident, therefore, that three phosphorus atoms have each lost one electron to a fourth atom:

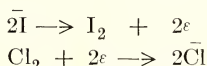


The reaction is commonly written:



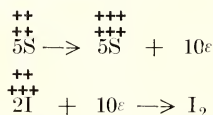
The preparation of iodine from either an iodide or an iodate, the sodium salts for example, furnishes another good illustration of the truth of the statement that with the exception of double decomposition reactions our reactions in general chemistry are essentially electronic changes, commonly known as valence changes, and may be brought under the general classification of oxidation-reduction reactions.

In sodium iodide we have iodine with a negative valence of one, the iodine atom has one electron more than its normal quota. To secure the elementary iodine we must introduce an element that readily receives electrons, chlorine for example. Chlorine run into a solution of sodium iodide liberates iodine with the formation of sodium chloride:

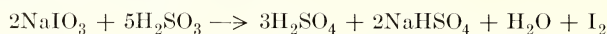


On the other hand, in sodium iodate we have positive pentavalent iodine, iodine atoms that have lost five electrons each from their normal

supply. To set the element free there must be added some compound containing an element that will readily give up electrons. Sulphurous acid suggests itself. Here we have positive tetravalent sulphur, sulphur atoms with a deficiency of four electrons each. But sulphur can lose comparatively readily a total of six electrons per atom, hence the sulphur atom in sulphurous acid has two electrons yet to spare. It is evident that we must have five atoms of this tetravalent sulphur for every two atoms of the pentavalent iodine:

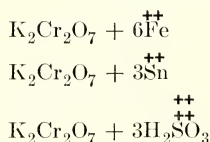


The reaction is commonly written:



A compound containing any element that may lose or gain more than some specific number of electrons, in other words change its valence, may be designated an oxidizing or reducing agent according to whether this element gains or loses electrons in the course of the reaction. Potassium dichromate, potassium permanganate, and nitric acid are common oxidizing agents. The capacity of these compounds to "oxidize" some other substance lies in the chromium, the manganese, and the nitrogen just as the reducing action of sulphurous acid, hydrogen sulphide, hydriodic acid, and stannous chloride lies in the sulphur, the iodine, and the tin.

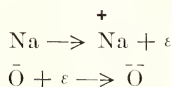
In potassium dichromate, $K_2Cr_2O_7$, for example, we have positive hexavalent chromium, chromium atoms with six less electrons than are found in the uncombined element. It readily takes up three, giving trivalent chromium, provided there is an element to supply these electrons. Such an element is found in iron, tin, sulphur, etc., in a ferrous salt, a stannous salt, sulphurous acid, or a sulphite. Bivalent iron loses an electron and passes into trivalent iron—a ferrous to a ferric salt. Bivalent tin loses two electrons, passing into quadrivalent tin—a stannous into a stannic salt. Quadrivalent sulphur loses two electrons and passes into hexavalent sulphur—sulphurous into sulphuric acid, a sulphite into a sulphate. It is a matter, therefore, of balancing the chromium against the iron, the tin, or the sulphur. Each two atoms of the chromium must oxidize six atoms of iron, or three of tin, or three of sulphur:



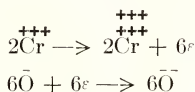
An interesting question arises just here: What would be the order of transition if the dichromate were added to a solution of ferrous sulphite or stannous sulphite? Would the electrons be supplied to the chromium simultaneously by the iron and the sulphur, or first by one and then by the other? If the latter is the rule, which would dis-

appear first, ferrous ion or sulphite ion? In other words, would the dichromate convert ferrous sulphite first into ferric sulphite and this then into ferric sulphate, or would ferrous sulphate be first formed and this then converted into ferric sulphate? Or would the two elements, iron and sulphur, act simultaneously, giving rise *pari passu* to ferric sulphate?

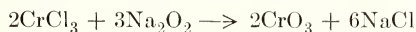
The reverse process, the loss of electrons by chromium when in contact with sodium peroxide, raises an interesting question. As is well known, if sodium peroxide is added to a solution of a chromic salt, chromic chloride for example, sodium chromate is formed; trivalent chromium is converted into hexavalent chromium. In other words, each atom of chromium has lost three electrons. What element in the sodium peroxide has received them? Surely not the sodium; then it must be the oxygen. As was said in a former paragraph, in peroxides oxygen must be regarded as having a negative valence of only one; each atom has received from some other element one electron only. So far as its chemical activity is concerned, sodium peroxide might be assigned the formula, NaO; the oxygen has received one electron from the sodium. To become the constituent of an ordinary oxide it must receive an additional electron. Under suitable conditions it may receive this from metallic sodium:



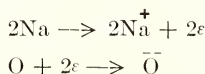
In the reaction of the peroxide with potassium dichromate the oxygen receives the electrons from chromium:



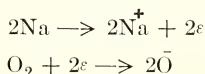
In the ordinary way the reaction is written:



It will be seen that sodium peroxide is of more than ordinary interest. When exposed to oxygen at ordinary temperature sodium is slowly converted into the monoxide, each oxygen atom taking one electron from each of two sodium atoms:

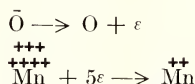


When the metal is brought in contact with the gas at a much higher temperature, each atom of the oxygen receives only one electron:



The attempt to explain the composition of sodium peroxide by a structural formula representing oxygen with a constant valence of two is inadequate.

Let us consider another interesting reaction, that between potassium permanganate and hydrogen peroxide in acid solution. Here positive septavalent manganese is reduced to bivalent manganese—a manganous salt—hydrogen peroxide is converted into water, and at the same time oxygen is evolved. We have the interesting phenomenon of two so-called oxidizing agents each reducing the other. In looking at the reaction from the standpoint of electronic transfer we are consistent in stating that reduction takes place in the manganese—the permanganate acts as the oxidizing agent. But how about the hydrogen peroxide? In this case there is oxidation in the oxygen—the hydrogen peroxide in this reaction is a reducing agent. The manganese atom has received five electrons. In hydrogen peroxide each atom of oxygen has one electron more than its normal quota and this it gives to the manganese. It is readily seen that this will require one molecule of the permanganate for each of the peroxide if the latter is written HO, or two if the peroxide is written H_2O_2 :



Is there any inconsistency in regarding hydrogen peroxide an oxidizing agent in its reaction with a chromic salt and a reducing agent in its reaction with potassium permanganate? There is none, any more than there is in designating zinc electronegative towards magnesium and electropositive towards copper.

To regard oxygen in peroxides as having a negative valence of one on the ground that its atom has received one electron from an atom of another kind, just as we ascribe to it a negative valence of two in ordinary oxides on the ground that its atom has received two electrons from one or more atoms of another element, is consistent with the view that elements in the uncombined state have a valence of zero on the ground that their atoms have neither given electrons to nor received electrons from atoms of another element, whatever forces may have come into play in the union of atoms of the same kind to form elementary molecules.

No one has yet offered a generally acceptable explanation of the fact that uncombined hydrogen and chlorine are found in the form of molecules of two atoms each, combinations, if we choose to call them such, of great stability, and yet when a mixture of equal volumes of the two gases is subjected to an electric spark or exposed to direct sunlight, hydrogen leaves hydrogen, chlorine leaves chlorine, and hydrogen and chlorine combine with tremendous vigor.

While persistent efforts have been made to demonstrate the existence of two distinct kinds of chlorine atoms, it cannot be said that these efforts have met with success. Should such a demonstration be made, we should be induced to believe that there must be two kinds of hydrogen atoms of opposite electrical properties, two kinds of oxygen atoms, two of nitrogen, and so on throughout the entire range of those elements whose properties are manifested by molecules of two atoms each.

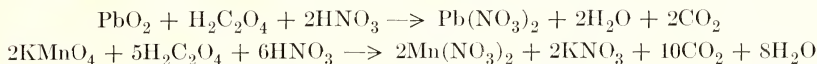
And what shall we say of those elements whose molecules consist of four atoms or six or perhaps even more according to conditions? It is not only in elements but also in compounds that we find this inexplicable capacity of particles of the same kind to become associated in what is evidently some other manner than mere physical juxtaposition. The application of X-rays has radically changed our former conception of crystalline structure, as is beautifully illustrated in such an apparently simple substance as sodium chloride. We think of this salt as a combination of one atom of sodium with one of chlorine, the molecule of two atoms being formed in some way by the transfer of one electron from the sodium atom to the chlorine atom, and we speak of the atom of sodium as now having a positive valence of one and the atom of chlorine as having a negative valence of one. When, however, we undertake to account for the currently accepted structure of crystalline sodium chloride, we find our efforts so far unsuccessful.

Let us conclude, therefore, that until we find more light on the nature of the forces operating between atoms of the same element and the relation between these inter-atomic forces and the electrons involved, we might do well to content ourselves with the interpretation of chemical action on the basis of the apparent transfer of electrons from one atom to another of different kind. The simple principles laid down in a former paragraph will serve as a guide and the application of these principles should give our students a clearer conception of the significance of chemical action than the meticulous care with which we are in the habit of presenting reactions in the form of balanced equations. We recognize the importance of chemical equations as ordinarily expressed but we are convinced that the deeper meaning of chemical action will become more apparent if attention is focused upon the valence changes and these are interpreted in terms of electronic transfer.

THE ANALYSIS OF ELECTROLYTICALLY DEPOSITED LEAD PEROXIDE BY THE METHOD OF LUX.

M. G. MELLON, W. F. REED, and H. L. WILKINS, Purdue University.

The lead in lead peroxide may be determined, according to Lux,¹ by dissolving the sample in nitric and oxalic acids and titrating the excess of the latter with potassium permanganate, the reactions involved being represented by the following equations:



Following the conditions recommended by Scott² for applying the method, an unsuccessful attempt was made to use it³ for a peroxide deposited electrolytically on platinum. The end point in the titration with permanganate was so indefinite that the method was abandoned as unsuitable for work requiring a precision of 0.1 per cent.

MacInnes and Townsend⁴ later published results directing attention to what they believed to be the merits of the method for determining the amount of lead in electrolytic deposits of the peroxide. In view of their conclusions regarding this electro-volumetric method, consideration was given to the procedure in two investigations⁵ in the hope that a careful reproduction of the conditions recommended by these investigators would eliminate the difficulties encountered earlier. The results obtained are summarized in the present paper.

It should be noted that the method of Lux has previously been subjected to adverse criticism and modified at various times.⁶ In addition, correspondence with chemists involved revealed the fact that the method is not used by a number of industrial concerns producing or using lead and its compounds nor considered satisfactory by the U. S. Bureau of Standards.

Present Work. Since an indefiniteness in the end point was the original point of difficulty in attempting to use the method of Lux, in making a study of the procedure consideration was given first to the

¹Z. anal. Chem. 19, 153 (1880).

²Standard Methods of Chemical Analysis, 1917, p 240.

³Mellon and Reinhard—Proc. Indiana Acad. Sci. 31, 181 (1921).

⁴Ind. Eng. Chem. 14, 420 (1922).

⁵W. F. Reed—Master's Thesis, Purdue University, 1923. H. L. Wilkins—Master's Thesis, Purdue University, 1926.

⁶Tocher—Farben-Ztg. p. 214 (1899); Joshua—Dissertation, Zurich (1906); Sacher—Chem. Ztg. 35, 731 (1911); Chwala and Colle—Z. anal. Chem. 50, 209 (1911); Ipiens—Ibid., 53, 261 (1914); Milbauer and Pivnicka—Ibid., 53, 575 (1914); Classen-Harriman—Quantitative Analysis, p. 245 (1902); Fresenius-Cohn—Quantitative Chemical Analysis, II, 623 (1919); Schaeffer, White and Calbeck—Chemical Analysis of Lead and Its Compounds, p. 72 (1922).

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

question of the effect of various factors upon the character of the color change involved in the titration of oxalic acid with potassium permanganate.

In carrying out this work the usual standards of careful analytical practice were maintained, such as the recrystallization of materials and the preparation of solutions with specially purified distilled water, the application (where necessary) of temperature corrections for volumes of standard solutions, and the standardization of potassium permanganate against sodium oxalate according to the recommendations of the U. S. Bureau of Standards.

Oxalic acid was first checked against the potassium permanganate according to the accepted scheme of adding about 15ml of sulfuric acid (1:4), diluting to about 100ml, heating to 80°C, and adding the permanganate until the appearance of a definite pink color which would persist for at least a minute. This titration was then repeated, using 40ml of 0.1 N oxalic acid, except for the addition of certain materials to the solution before titration. Four titrations were made in each case, the results in Table I representing an average of the values obtained.

TABLE I. The effect of various substances upon the titration of oxalic acid with potassium permanganate.

Exp. No.	Substance Added	KMnO ₄ Required	Percentage Error	End Point
1	15ml H ₂ SO ₄	40.15 ml	.....	good
2	30ml HNO ₃ *	39.0	2.8	fairly good
3	15ml H ₂ SO ₄			
	0.5g PbSO ₄	39.7	1.0	fairly good
4	15ml H ₂ SO ₄			
	0.5g Pb(C ₂ H ₃ O ₂) ₂	39.0	2.8	fairly good
5	15ml H ₂ SO ₄			
	0.5g Pb(NO ₃) ₂	38.5	4.0	fairly good
6	30ml HNO ₃			
	0.5g Pb(NO ₃) ₂	39.0	2.8	poor
7	15ml H ₂ SO ₄			
	30ml HNO ₃			
	0.5g Pb(NO ₃) ₂	38.5	4.0	poor
8	15ml H ₂ SO ₄			
	30ml HNO ₃			
	0.5g Pb(NO ₃) ₂			
	KOH†	37.7	6.0	fairly good

* 1 : 2 acid

†Sufficient base to neutralize the nitric acid before adding the sulfuric.

The above data are in accord with the work of Ipiens⁶ to the extent that it seems to be the lead and the nitrate ions which together cause a slow fading of the permanganate, rendering the titration tedious as the end point approaches. Moreover, there was a marked decrease in the amount of permanganate required when either undissolved lead sulfate was present, or when nitric acid was substituted for sulfuric.

Several additional sets of titrations were then made in order to determine the effect of making certain changes in the general procedure. For these only a general statement is included, indicating the significant conditions and the results obtained.

In one set Experiment No. 2 was repeated, varying the quantity of nitric acid, the time of standing before titration, and the temperature

while standing. At first, increasing amounts of nitric acid required the use of decreasing amounts of permanganate, but as the concentration of acid was further increased slightly more permanganate was again required, indicating a possible connection with the fact that concentrated nitric acid will itself slowly decolorize potassium permanganate. For the latter action, the rate at room temperature is much slower than that at 80°C. As dilution of the acid decreases the rate of the reaction, the total effect for the concentrations maintained in using the method of Lux is probably small. Nitric acid through which air had been bubbled for some hours greatly reduced the effect observed with the more concentrated solutions containing untreated acid. With 30ml of nitric acid (1:2) present, no appreciable change in the volume of permanganate required was noted on allowing the solution to stand at room temperature up to two hours before titration. With the latter quantity of nitric acid again present, a small decrease, directly proportional to the time of standing, was noted when the solution was maintained at the temperature of boiling water for a time before titration.

On repeating Experiment No. 3 it was found that increasing amounts of lead sulfate necessitate the use of slightly decreasing amounts of permanganate.

The first two experiments recorded in Table I show a discrepancy indicating an error inherent in a method where calculations are based upon a permanganate solution whose value is determined in the presence of sulfuric acid but whose actual use is in connection with nitric acid. The conditions of standardization do not duplicate those of actual use. Milbauer and Pivnicka⁶ must have recognized this for they suggested using urea to avoid the deleterious effect of nitric acid. For the use of urea the following conclusions were reached in the present work: (1) The addition of 0.3g of urea when titrating in the presence of sulfuric acid alone produced no effect; (2) when titrating in the presence of nitric acid alone, the same amount of urea had some beneficial effect, but the amount of permanganate required was still much too low, compared with the amount required when sulfuric acid alone was used.

The possibility of some action of nitric acid on oxalic acid⁷ under the conditions of titration was not investigated.

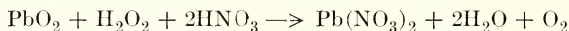
In order to try the procedure of MacInnes and Townsend on ordinary lead peroxide, a commercial sample was ground to 200 mesh size and analyzed by the authors and by several students for the content of lead. The results varied between 82 and 86 per cent. Different amounts of nitric and oxalic acid were used. As the amount of permanganate necessary to oxidize the excess oxalic acid was decreased (and hence the lead calculated was increased) by increased amounts of oxalic and nitric acids, it would seem necessary, as already intimated, to standardize the solution under conditions approximating those prevailing in actual use.

The general effect of making titrations under the above conditions is to bring a positive error into the determination. Another set of observations revealed the possibility of an effect partially compensating

⁷ Atti Acad. Lincei (5) 16, 399 (1907); *Compt. rend.* 124, 1349 (1897).

that just mentioned, at least in the determinations of MacInnes and Townsend. In order to check the precision of the method they dissolved a known weight of lead in nitric acid and then deposited the element electrolytically as the peroxide. Their calculations were then based upon the assumption that all the lead was deposited. Time after time in the present work it seemed impossible to make the electrolytic separation sufficiently complete to prevent obtaining a test for lead by precipitation as the chromate, according to the method of Falk.⁸ This would mean a deposit containing an amount of lead slightly less than that dissolved.

The Method of Schlossberg. As already indicated, the authors' experience with the method of Lux was unsatisfactory for work requiring a precision of 0.1 per cent. However, owing to the evident value of the suggestion of MacInnes and Townsend for avoiding, by means of a titrametric estimation, the difficulty of determining with satisfactory precision the amount of lead in an electrolytic deposit of the peroxide, attention was directed to the possibility of substituting some other solution for the oxalic acid to react with the lead peroxide. The most promising substance seemed to be hydrogen peroxide. This compound reacts with lead peroxide, in the presence of nitric acid, according to the equation



Schlossberg⁹ originally proposed it as a substitute for oxalic acid in the method of Lux. Unfortunately, hydrogen peroxide, in contact with platinum electrodes, decomposes more or less rapidly, thus introducing a complication not yet overcome. During the course of experiments with it, however, certain information was obtained which may be mentioned as being of interest when one compares it with similar information for oxalic acid. On repeating part of the experiments reported in Table I, with the substitution of commercial hydrogen peroxide for oxalic acid, it was found that the quantities of lead nitrate, lead sulfate, and nitric acid indicated therein produced no effect on the titration, allowing for an experimental error of 0.1 per cent. This indicates some connection between the use of oxalic acid and the unsatisfactory results obtained with the method of Lux.

⁸ J. Am. Chem. Soc. 32, 1564 (1910).

⁹ Z., anal. Chem. 41, 735 (1902).

FOOD FAKES AND FANCIES.

R. H. CARR, Purdue University.

The large number of new food substances which are daily finding a place on the market makes a real problem not only for the inspector who must keep posted on all of them but more so for the average customer who no longer attempts to become informed on all the things he feels the need of purchasing any more than he feels the need of being informed on the qualifications of those for whom he chooses to vote.

"Best in the World." The buying world has become so accustomed to such extravagant claims as "fully guaranteed," "your money back," and many others, that it has learned to buy on faith. If the food is unsatisfactory it is usually avoided in the future and thus an elimination contest begins. Often it happens that the news of food frauds exposed by some investigating bureau never reach the man in the street and he continues to patronize a fraud because the high-pressure salesman has led him to believe this product is the "best in the world" and the halo thus developed for a commodity lingers in the purchaser's mind for a long time.

Fake Foods in Foreign Countries. There is probably less trouble from dishonest food in this country than elsewhere, due to the watchfulness of our food inspectors. According to a recent report from Paris, inspectors called attention to 728 articles taken for investigation and found 396 were falsified in some way. There was everything from watered milk, synthetic wine, and chocolate that contained no chocolate, to sugar that contained no sugar. There was coffee made from a mixture of wheat and chestnut flour and milk made from chalk, sheep brains, gum arabic, fat and sugar, probably the product of a French model of Ford's mechanical cow. There are few such flagrant food violations to contend with in this country. Many of those which require attention are borderland cases, as it were, which are concerned with foods of questionable usefulness or of uncertain value for money expended. Only a few of the more common will be discussed here, such as (a) foods of questionable vitamin value, (b) the mineral content of foods, (c) under size or weight of foods, (d) super foods and (e) breakfast foods.

Vitamin Foods. Among the vitamin foods widely sold at the present is cod liver oil which contains vitamins A and D in rather concentrated form. This has caused a wide demand for this oil, not only for human consumption but also for poultry and other live stock. The supply has been rather limited, hence the temptation has been great to mix this oil with vegetable oils which carry but small amounts of these vitamins.

It has been estimated that the so-called "cod liver" oil purchased for chicken feed alone during the past year was ten times greater than the total available supply of the pure cod liver oil. The vitamin value of this oil is often over-rated and the purchaser is usually dependent upon the standing of the company that sells the product.

Super Food. Santogen is a compound made up largely of casein and has been proclaimed as a scientific achievement,—a "gift from the Goddess of Health." It was proclaimed to have "700 per cent more tissue-building, life-sustaining nourishment than wheat flour," but laboratory analysis showed it to be less valuable than an equal weight of wheat flour. This food was concocted to attract people of wealth, as it was only advertised in high-class periodicals. Its extensive sales proved there are lots of suckers among people of means.

Mineral Foods. Have you had your iron today (or raisins)? is a question that has confronted nearly everybody in street cars, cigar stores and newspapers. It is a good question to raise, but a hard one to answer, as only a few foods contain iron in a form suitable for good assimilation. Thus onions and raisins both contain about the same percentage of iron (0.0006) but onions seem to be greatly superior to raisins and also to many other foods containing a much higher iron content when an attempt is made to select a diet suitable to replace blood iron which was given for transfusions.

Small Eggs, Underweight Bread and Butter. Another form of a fake is the selling of small eggs by the dozen where the law does not require them to be sold by the pound. This has developed into quite a business in some states, resulting in large numbers of eggs being shipped to regions where they can be marketed without danger of being rejected. Short weight in bread to consumers is estimated to have caused a loss of \$75,000,000 annually in the United States. Much of this loss occurs in cities where loaves which weigh only about 12 ounces are sold for nine cents as 14-ounce loaves. This is easily possible where few have scales that weigh accurately and fewer still can estimate the difference between a 12 and 14-ounce loaf. What has been found true for bread shortage also holds for weights in butter, especially for the 4 and 8-ounce sizes, which are most often found to be underweight. Here, as in many other food products, the safest plan seems to be in choosing as reliable brands as possible.

Breakfast Foods. Probably there are no articles of diet which cause the consumer more wonder as to their real value as foods than the large number of breakfast foods on the market. Can one depend on securing pep from a "pep" breakfast food? There are a large number of breakfast foods made out of wheat and widely advertised as highly nutritious foods, but after considerable investigation the writer has been unable to find one as valuable and nutritious as the wheat was before being treated, when measured by its ability to sustain the life of an animal. The bran breakfast foods have become quite popular in recent years, and sell at a price which would make agriculture profitable if the

grower got his share of the profits. However, the indiscriminate use of fibrous foods in overcoming constipation is questionable, as it seriously interferes with digestion, especially in the stomach, although it may serve to relieve constipation temporarily, through the increased bulkiness in the intestines of this large unused residue of the food.

Conclusion. In general it is questioned by Haldane whether any food product in a can or package is equal in food value and vitamin and mineral content to the raw materials from which it was derived. If this is the case it calls for more intelligent handling and careful research in foods if those living in cities far from the sources of the raw food material are to be maintained in health on a par with those located in the rural districts where much of the diet is composed of fresh fruits and vegetables. Many other examples of questionable foods might be mentioned but enough has been given to indicate that when the dollar goes on an adventure to a grocery store it is about as apt to meet a Waterloo as win a bargain battle.

AN EFFICIENT STIRRER FOR GAS ABSORPTION.

A. F. BENNING, University of Notre Dame.

The most convenient way of increasing the rate of absorption of a gas in a liquid is to increase the surface of contact between the two. There are many ways of doing this, but the most of them are not applicable to laboratory work.

An efficient and simple way of increasing this surface of contact is to use a stirrer designed to distribute the gas throughout the liquid in

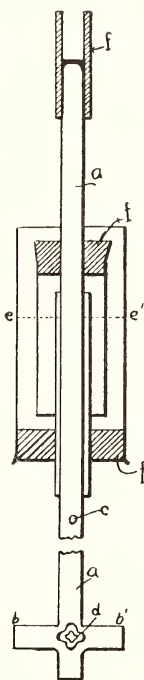


Fig. 1—Construction of stirrer: a, shaft; bb, stirring arms; c, gas entrance; d, constricted area; ee, mercury level; f, rubber connections.

the form of fine bubbles, or, better still, atomize the liquid in the presence of the gas.

An easily constructed stirrer for this purpose can be made by sealing two short glass tubes "bb" (fig. 1) close to one end of a straight piece of glass tubing "a" long enough to serve as a shaft for the stirrer. The end of "a" below "bb" is just long enough to reach the liquid when

the stirrer is rotated with the arms "bb'" just free of the surface. The upper end of the shaft "a" is closed and a small hole is blown in the lower part to permit the entrance of the gas. The junction of the four tubes is constricted so that the cross-section is smallest at that point.

If this stirrer is rotated with the arms under the surface, the liquid will flow from the lower tube to the ends of the arms. Because of the contraction at the junction and the friction loss at the liquid entrance, the pressure at the center of the arms is reduced, drawing gas down the shaft through the hole "c." The liquid and gas are forced out the ends of "bb'," resulting in the gas being distributed through the liquid in the form of fine bubbles.

If the stirrer is raised so the arms are just free of the surface, gas will be drawn from the hole in the shaft and liquid through the lower tube; the two will be intimately intermixed and sprayed throughout the gas space in the containing vessel. This provides an enormous contact surface with a corresponding absorption rate.

In practice this stirrer must be rotated at a fairly high rate of speed and to prevent vibration, or rather to allow the stirrer to align itself, it should be flexibly connected with the driving mechanism. This can best be arranged by connecting the shaft with the driving axle by means of a short piece of pressure tubing. If a mercury seal is used, as is generally the case, all of its moving parts should be flexibly connected with the shaft by means of a rubber stopper or similar flexible joint.

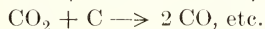
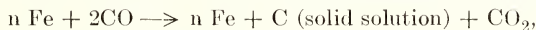
In one particular case it was found that a stirrer of this type reduced the time of absorption from 28 to three hours.

CASE-CARBURIZATION IN PRESENCE OF
FERROSILICON.

R. C. SPENCER and E. G. MAHIN, University of Notre Dame.

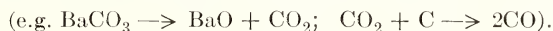
Case-carburization or case-hardening is a process of partial cementation whereby a surface layer or "case" of high-carbon steel is produced upon soft or low-carbon steel. The process involves heating the steel in contact with carbon or some substance capable of imparting carbon to the iron in such a form that it may be assimilated. When this case is hardened by quenching from elevated temperatures it is very resistant to wear or abrasion, while the soft, ductile core reduces the danger of breaking under shock or impact.

Cementation is usually understood to be a reaction of iron with either carbon monoxide or cyanogen, somewhat as follows:



It seems probable that these reactions take place at the surface of the steel and that the carbon then migrates or diffuses through the austenite, which is the stable form of iron at carburizing temperatures (around 950° C.).

Many different substances may be used as carburizing materials. Solids, such as carbon, petroleum coke, charred leather; liquids, such as fused alkali cyanides and ferrocyanides; and gases, such as hydrocarbons and carbon monoxide; all of these serve particular needs. The solid carburizing materials are, perhaps, the most important, especially for the formation of deep cases. Most of these have an energizer, such as sodium or barium carbonate, mixed with them in order to give a potential source of carbon monoxide at the high temperatures



Due to the long period of heating above the critical temperature, considerable grain growth occurs. Coarse grain structure is not desirable because of the lower strength characteristics which accompany it. In order to refine the grain structure and also to produce metastable constituents which make the steel much stronger and harder, the case-carburized piece is subjected to thermal treatment. The piece may be heated and cooled as many as three times, first, heating to above the critical temperature of the core, followed by drastic quenching in order to refine the core; second, heating to above the critical temperature of the case, followed by a drastic quenching in order to harden and refine the case; and third, heating to below the critical temperatures, followed by slow cooling in order partially to relieve internal stresses.

During the time of drastic quenching enormous stresses are set up within the metal. These stresses may cause warping or cracking.

If carbon is absorbed too rapidly or if the time of carburization is prolonged the carbon content of the surface layers of the piece will rise above 0.87 of one per cent, which is the carbon content of the iron-iron carbide eutectic. Upon cooling such a carburized specimen to the upper critical temperature, cementite (iron carbide) begins to separate and continues to do so until the lower critical temperature is reached. This cementite is precipitated or thrown out of solid solution at the grain

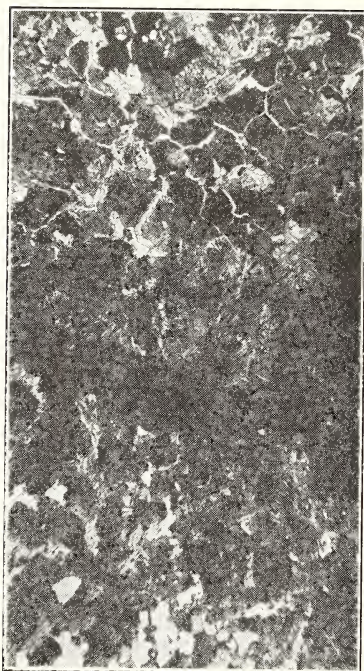


Fig. 1—Structure of the case formed on ingot iron by heating to 950° C. for 5 hours in a commercial carburizing material.

Specimen No. 36
 Echant HNO₃
 Magnification 75
 (Reduced one-third.)

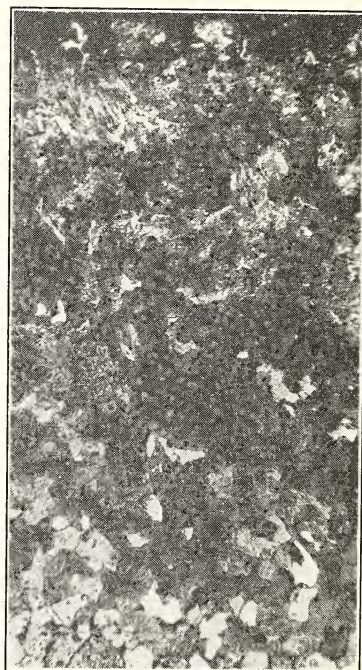


Fig. 2—Nature of case produced by a commercial carburizing material which has had 20% ferrosilicon mixed with it. Heated 5 hours at 950° C.

Specimen No. 35
 Echant HNO₃
 Magnification 75
 (Reduced one-third.)

boundaries. Consequently, a hypereutectoid zone will result, this being composed of grains of eutectic composition surrounded by iron carbide shown as a bright network in section (fig. 1). When the carbon content is high enough some of the iron carbide is precipitated also along the atom planes of the austenite grains and below the lower critical point it is found as plates or flakes in the pearlite grains (the iron-iron carbide eutectoid).

When the piece is subjected to hardening processes and high internal stresses are induced, these plates, as well as the brittle envelopes,

offer easy paths for the course of a crack or fracture. For this reason a case which has a hypereutectoid zone is usually not desirable.

Also if carbon penetration is too rapid, resulting in abrupt changes in carbon content from one layer of the case to the one immediately beneath it, peeling, flaking or chipping is likely to occur.

Consider what happens upon quenching a carburized specimen. The surface will be chilled first and it will contract. This may be relieved in part by compression of the lower layers and in part by deformation of the outer layer. As the next layer contracts the outer layer becomes too large and tensile stresses are developed between these layers. If we have carbon segregation and abrupt changes in carbon composition there will be weak points, and cracks started due to the stress may cause parts of one layer to break or peel away from the layer beneath. This takes place in the type of failure known as "exfoliation," where a surface layer breaks away in the form of a shell or coating. This method of fracture is also likely to be noticed at corners and bends.

For several years carbon migration and segregation in steel have been subjects of investigation. In some experimental work described in an earlier paper¹ it seems to have been definitely proved that elementary carbon can dissolve in and migrate through iron. Also that certain ferro-alloys, such as ferrosilicon and ferromanganese, increase the rate at which carbon migrates from cast iron drillings, used as a packing, into specimens of ingot iron. In this process ferromanganese proved to be more efficacious as an energizer than other materials used.

Naturally this suggested the possibility of using such materials in the carburizing mixture for partial cementation processes and a series of experiments with this idea in mind has recently been conducted.²

It was found that ferrosilicon, ferromanganese and ferrophosphorus did have an effect upon the rate at which carbon was absorbed when they were mixed with the carburizing material. Ferrosilicon especially had a decided effect upon the nature and depth of case produced and it was thought worth while to study in more detail the action of ferrosilicon in case-carburization processes.

From earlier experiments² we were led to the conclusion that ferrosilicon, when added to the carburizing material, has a desirable influence, first, because it gives a case that has an even gradation in carbon content from the highest carbon content at the surface to the low carbon content of the core, and, second, because for ordinary temperatures and times of carburization (5-8 hours at about 950° C.) no hypereutectoid zone is formed.

The experimental work was conducted in the following manner: Specimens about an inch and one-half in length were cut from one-half inch ingot iron rods. These were packed individually in the carburizing material in Nichrome carburizing pots, each about 5 inches in height and 3 inches in diameter. The pots were heated in a Hoskin's electric muffle furnace and the temperature was regulated by means of a Hoskin's Chromel-Alumel thermocouple and pyrometer. The commercial

¹ Mahin and Spencer: *Proc. Ind. Acad. Sci.*, 34, 1924 (1925).

² Spencer: Master's Thesis, University of Notre Dame, August, 1926.

carburizing material was obtained from the Rodman Chemical Company and bears the trade mark "Carbo." The ferrosilicon, a solid solution of silicon and iron (this was 50 per cent silicon), was obtained from the Clark Equipment Company of Buchanan, Michigan. Both materials were ground to about 50 mesh, and when ferrosilicon was mixed with the commercial material, as homogeneous a mixture as possible was made by careful rolling on glazed paper.

This effect of the addition of ferrosilicon may be noticed by comparing figures 1 and 2. Figure 1 shows the type of case that is obtained by carburization in the commercial materials alone. The hypereutectoid zone is fairly wide and well defined. The eutectoid zone is very poorly defined and carbon gradation is decidedly uneven.

Figure 2 shows the nature of the case produced by carburization in a commercial material which contains 20 per cent of ferrosilicon. The hypereutectoid zone is absent and carbon segregation and gradation are more even.

Table I gives a comparison of the carbon penetration and thickness of different zones.

TABLE I. Comparison of depths of carbon penetration with and without addition of ferrosilicon.

		5 hrs. at 950° C.	7 hrs. at 950° C.	9 hrs. at 950° C.
Specimen carburized in commercial material.	Total penetration	1.6 mm.	2.30 mm.	2.94 mm.
	Eutectoid zone	0.67 mm.	1.10 mm.	1.52 mm.
	Hypereutectoid zone...	0.2 mm.	0.66 mm.	0.90 mm.
Specimen carburized in mixture with 20% of ferrosilicon.	Total penetration	1.13 mm.	1.74 mm.	2.50 mm.
	Eutectoid zone	0.40 mm.	0.69 mm.	0.84 mm.
	Hypereutectoid zone...	0.00 mm.	0.00 mm.	(0.30)* mm.

*The hypereutectoid zone occurred only locally, over about one-third of the case.

Whatever may be the mechanism of the action of ferrosilicon in causing these differences, it seemed reasonable to suppose that it was only the ferrosilicon immediately surrounding the specimen that was affecting the nature of the case. Consequently, a number of pastes or paints containing ferrosilicon were made and tried on different specimens. A paste made of one part by volume of water-glass to one part by weight of ferrosilicon gave approximately the same type of case as did the original 80-20 mixture. The paste was applied by simply dipping the specimen into the water-glass-ferrosilicon mixture. This was allowed to dry on the specimen and the whole was packed in ordinary unground commercial carburizing material.

In one experiment where only one side of the specimen was dipped into the paste, the exact point at which the influence of the ferrosilicon stopped could be determined from the nature of the case when the specimen was prepared and observed over the microscope.

Since, for ordinary temperatures and times of carburization, the case produced when ferrosilicon is used in the carburizing material has no hypereutectoid zone, and also since the carbon content decreases

gradually from the eutectoid zone towards the core, the use of ferrosilicon in a carburizing material should prove desirable in this respect at least. Cases having only eutectoid composition at the surface and a relatively deep penetration of carbon may be prepared by heating for shorter periods of time at higher temperatures than are ordinarily used for the production of such a case.

The work presented here represents a part of more comprehensive experiments which are in progress at the present time, this investigation forming the basis for a thesis by one of the authors (Spencer) for the Doctorate.

COLLOIDAL ARSENIC TRIOXIDE IN THE ARSENIC DETERMINATION.

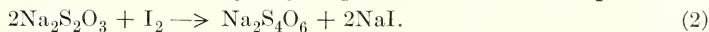
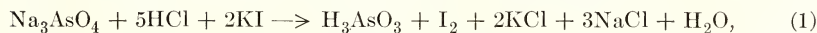
E. G. MAHIN AND A. F. DOYLE, University of Notre Dame.

Arsenic is an essential constituent of various commonly used insecticides. In such materials it may occur in either state of oxidation (trivalent or pentavalent) and as either free acid or combined as salts—arsenites or arsenates. Paris green is a double copper salt of acetic acid and arsenous acid, of variable composition, but the commercial article may contain also cupric arsenate or free arsenous or arsenic acid. As these compounds vary in solubility, insecticidal efficiency and effect upon foliage, methods for their determination are necessary; but one determination that is always of first importance is that of total arsenic.

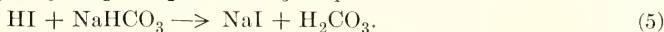
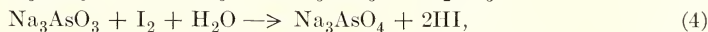
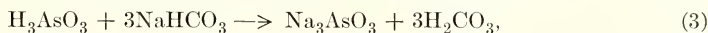
For this determination two methods have at various times been made official by the Association of Official Agricultural Chemists. Until the publication of the revision of 1919, the official method for total arsenic¹ was, in outline, as follows:

The weighed sample is heated with a solution of sodium hydroxide until decomposition is complete. Cuprous oxide is precipitated, the solution then containing sodium acetate, sodium arsenite and sodium arsenate. The last named salt is from oxidized arsenic already existing in the sample, as well as from arsenite which has been oxidized during the process of digestion with the basic solution.

The pentavalent arsenic is then brought to the trivalent form by the addition of hydrochloric acid and potassium iodide, followed by careful removal of liberated iodine by sodium thiosulphate:



An excess of sodium bicarbonate is then added to maintain the solution in a weakly basic condition, after which the arsenic is titrated by standard iodine solution, by the aid of starch as an indicator:



¹ Bur. Chem., Bull. 107, 25 (1908).

This method is convenient and it gives accurate results, but one difficulty is occasionally experienced in routine determinations. At the point where iodine is to be removed from the solution of reduced arsenic (equation (2)) it is not permissible to add starch as indicator, because in the strongly acid solution there would be partial inversion of starch, with the formation of erythrodextrin, this giving a persistent red color with iodine and thus interfering with the subsequent titration.

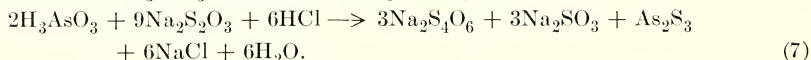
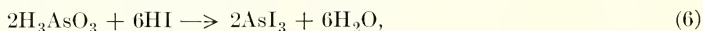
In the absence of starch the exact removal of iodine must be accomplished through observation of the disappearance of the faint yellow color of iodine alone. This may readily be done if the reactions proceed normally. But it sometimes happens that toward the end of this step a yellow color develops from another source and deepens as the addition of sodium thiosulphate proceeds; in such cases it becomes practically impossible to determine when the correct amount of thiosulphate has been added.

With the publication of the revised methods of the Association of Official Agricultural Chemists in 1919 the method as above described was abandoned and that of Roark and McDonnell² was substituted. In this method the sample of Paris green is placed in a distilling flask with hydrochloric acid and cuprous chlorid, the liquid then being distilled and the distillate, containing hydrochloric acid and arsenic trichloride, is later neutralized and titrated with standard iodine solution.

This method is reliable but it requires assembled apparatus, consumes considerable time and requires rather close attention during the progress of the distillation. In the opinion of the present authors the older method is preferable, provided that some method may be found for obviating the difficulty which comes through the development of color as the arsenic is reduced.

It was with the purpose of discovering the cause of this secondary development of color, as well as to find the conditions under which color might or might not develop, that the present investigation was undertaken.

As theoretical possibilities, this color might be due to the formation of sols of either arsenic trisulphide or arsenic triiodide, both of these compounds readily going into the colloidal state:



The details of the (slightly modified) procedure are as follows:³

To 2 gm. of Paris green in a 250 cc. flask add about 100 cc. of a 2-per cent solution of sodium hydroxide. Boil until all of the green compound has been decomposed and only red cuprous oxide remains. Cool, filter into a 250 cc. volumetric flask, washing the paper well, dilute to the mark and mix.

Measure 50 cc. of the solution into a 250-cc. flask and concentrate by boiling to about half the original volume. Cool to 60° and add 10 cc.

² J. Ind. Eng. Chem., 8, 327 (1916); A. O. A. C., "Methods of Analysis," p. 53 (1919).

³ Mahin: "Quantitative Analysis," 3rd ed., p. 245.

of concentrated hydrochloric acid and 1 gm. of potassium iodide. Mix and allow to stand for ten minutes. From a burette carefully add tenth-normal sodium thiosulphate solution until the iodine is all reduced. Starch must not be used but care should be exercised in reaching the end point. If a persistent yellow color develops at this point, use starch solution as an outside indicator, touching drops of the titrated solution to the starch. If the end point has been passed, add iodine solution until the iodine-starch reaction is barely produced.

Allow to stand for five minutes longer and if iodine color reappears, carefully add more thiosulphate solution. Immediately add, as rapidly as may be done without loss by effervescence, 15 gm. of sodium bicarbonate, free from lumps. Titrate at once with standard iodine solution, deferring the addition of starch until near the end point. Calculate the percentage of total arsenic, expressed as arsenic trioxide, in the Paris green.

Experimental. Weighed portions of Paris green were treated as above until the diluted basic solution of arsenic was obtained. Measured portions of this solution were taken for the titrations, the conditions being varied as to temperature and as to the relative amounts of hydrochloric acid and potassium iodide added, other conditions being maintained as already described.

Experiment 1.—The temperature was held at about 20°, instead of the specified 60°. Other conditions being unchanged, potassium iodide was varied in the determinations from the prescribed 1 gm. to a maximum of 40 gm. The solutions remained colorless upon reduction, until the one containing 30 gm. was reached; in this solution a persistent yellow color developed.

Experiment 2.—The temperature was held at 60°, as specified, during the reduction period, and the quantity of potassium iodide was again varied. A yellow color developed as soon as the specified quantity of 1 gm. had been exceeded.

Experiment 3.—With conditions otherwise the same as in the preceding experiment, the quantity of hydrochloric acid was reduced to 5 cc. The results were the same as in the preceding experiment.

Experiment 4.—The amount of acid was further reduced to 2.5 cc. No yellow color developed until the quantity of potassium iodide added had reached 15 gm., but the reduction of arsenic was slow, and probably incomplete.

Experiment 5.—With a temperature of 60° for the reduction period, as in experiments 2, 3 and 4, the potassium iodide was fixed at 2.5 gm. and the acid was varied from a minimum of 1.25 cc. to a maximum of 15 cc. No color was produced after reduction of any of these solutions, but reduction was incomplete in the more dilute acid solutions.

Experiment 6.—The acid was fixed at 5 cc. and the potassium iodide at 3.75 gm., while the reduction temperature was varied between 25 and 90°. No color developed in any of the solutions after reduction.

Conclusions.—The persistent yellow color which is sometimes formed toward the end of the reduction of arsenic acid by potassium iodide, hydrochloric acid and sodium thiosulphate is not due to the formation of sols of arsenic trisulphide, because this colloid is readily flocculated by concentrated hydrochloric acid, which is here present. The conclusion seems obvious that arsenic triiodide is formed in a colloidal state, in presence of an excess of potassium iodide.

With conditions maintained as in the official method, no interfering color is formed during the reduction, unless the specified quantity of 1 gm. of potassium iodide is exceeded. Variation in acidity within reasonable limits has no undesirable effects, so far as development of color is concerned, but it is necessary to exercise care in weighing the iodide to be used in the reduction. No doubt a lack of appreciation of this requirement has been responsible for the apparently erratic results often observed by analysts, who have thought that they were following the same method in all cases.

The older method, as herein outlined, seems preferable to the distillation method of Roark and McDonnell, which is now official. If the analyst will exercise some care in the addition of potassium iodide he will experience no difficulty in obtaining accurate and reliable results.

THE DIFFUSION OF HYDROGEN IN IRON.

E. G. MAHIN, University of Notre Dame.

It is quite well known among metallurgists that metals may dissolve various gases, sometimes in fairly high concentrations. This is especially true for metals in the molten state and gases so dissolved are partly expelled when the metals crystallize during solidification, this action resulting in troublesome "blow holes," which are merely gas pockets occurring through the mass of solid metal.

It seems practically certain that, within ordinary temperature ranges, most gases may enter into metallic solution only if the gas be in the atomic state. But if a gas is liberated from a compound, in direct contact with a clean metal surface and by reaction of the compound with the latter, solution is relatively easy because the gas is then in the nascent state.

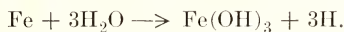
This action is especially important in connection with the operation of cleaning sheets of iron or mild steel to prepare them for coating with tin, zinc or enamel. During the process of rolling the metal into sheet it becomes coated with iron oxide which, if not first removed, will effectively prevent the second metal alloying with the iron surface, during the tinning or "galvanizing" process. In order to remove this oxide coating the sheets are "pickled" in hydrochloric or sulphuric acid. The concentration, temperature and duration of application of the acid are so chosen as to effect complete removal of scale, with a minimum of attack upon the metal underneath. But under any circumstances there

is some solution of free iron, with the formation of ferrous sulphate (or ferrous chloride) and hydrogen.

When hydrogen is evolved by a reaction between a metal and an acid, much of it ordinarily escapes as bubbles of gas. This is due to immediate combination of the atoms of hydrogen to form diatomic molecules of ordinary gaseous hydrogen. But if the nascent hydrogen is in contact with any other substance with which it can react (an oxidizing agent) it is not so evolved. Similarly, if any solvent for atomic hydrogen were present at the moment of liberation, thus preventing intercombination of the separate atoms, such solution could occur at the surface of attack by the acid from which the hydrogen is liberated.

This would appear to be true in the case of iron and acids. At ordinary temperatures gaseous (molecular) hydrogen will not dissolve in iron. But during the pickling of iron or steel sheets considerable quantities of hydrogen are absorbed, this element diffusing into, and ultimately through the sheets. If such dissolved hydrogen is not removed by a subsequent annealing the metal will be found to have become quite brittle. Frequently also small blisters appear in the sheet during the coating process.

Embrittlement of steel by hydrogen sometimes occurs in other cases. For example, steam boilers occasionally become brittle and yield to internal steam pressure. This is thought to be due to absorption of hydrogen from alkaline water, due to such a reaction as the following:



Most of this hydrogen escapes as the molecular gas but some of it dissolves in the ferrite, or iron grains, of the steel.

All metals in the normal condition possess a crystalline structure. Regular crystal outlines are not always observed but in such cases the mass of the metal is composed of irregularly formed grains, whose internal structure is certainly crystalline in character. When a section of a low-carbon steel is polished and etched with a dilute acid, microscopic examination reveals a structure like that of figure 1. In this photomicro-

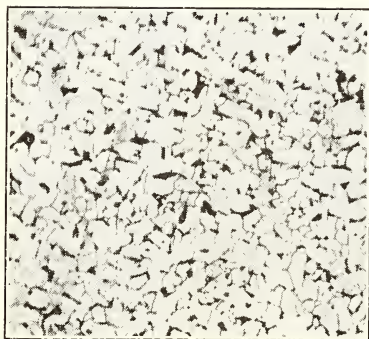


Fig. 1—Photomicrograph of a low-carbon steel, 100x.
(Reduced one-third.)

graph the bright portions are grains of ferrite, or carbonless iron. The small dark grains are of pearlite, the eutectoid of iron and iron carbide, while the network of fine, dark lines consists of grooves produced by the action of the etchant upon the grain boundaries, which are of supposedly amorphous metal.

The mechanism of solution and diffusion of hydrogen in iron has not been thoroughly understood, although considerable attention has been given to the problem. A partial bibliography of the subject of hydrogen solution and of embrittlement of steel has been given by Edwards.¹ This indicates that the first recorded observation of the general phenomenon was made by Cailletet² and that many others have studied various phases of the question since that time.

Edwards studied the influence of variation in time and temperature, and in concentration of hydrochloric and sulphuric acids, upon the rate of solution and diffusion of hydrogen. His method consisted in allowing the acid to act upon one side of a clean sheet of hot-rolled mild steel, the hydrogen which diffused through to the other side being collected and measured. He found that at 18° C. the rate of diffusion increased rapidly as the concentration of sulphuric acid was increased from 5 to 15 per cent, but slowly for further increase in concentration. For acid of a given concentration (tenth equivalent normal) the rate of solution and diffusion was practically inversely proportional to the temperature.

In order to account for the formation of blisters in pickled sheet, before or after annealing, Edwards advanced the following theory:

Hydrogen dissolves in the steel in the atomic state and diffuses in this form. When the atoms reach any surface they unite to form diatomic—ordinary gaseous—hydrogen. If the surface so reached is the exterior surface of the sheet, the gas simply escapes. But if this surface is at some discontinuity of the metal, however small this may be, gas pressure is generated and a blister is developed, either at once or during the heating for annealing or coating. That such pressures may become very large was shown by Cailletet,² who proved that diffusion through the metal may take place against an opposing pressure as high as fourteen atmospheres.

Discontinuities which might serve in this way may be present at the numerous non-metallic inclusions of microscopic dimensions, always found in iron and steel, as well as at larger flaws in the form of blow holes and at accidentally enclosed particles of iron oxide.

It has been supposed by Andrew³ and others that hydrogen diffuses largely or entirely through amorphous grain boundaries and that its solubility in the crystalline body of the grains is very small. This assumption would account, in a way, for the intercrystalline brittleness usually noticed in pickled steel. If this were true a fine grained metal should permit greater freedom to the passage of gas than a coarse grained one, since in the former case there is a greater relative quantity of the amorphous phase. Edwards made a single test of this theory by observing the rate of diffusion through two sheets, one of which was

¹ J. Iron and Steel Inst., 110, 9-44 (1924).

² Comp. rend., 66, 847 (1863).

³ Trans. Faraday Soc., 9, part 3 (1914).

made from a single large grain of iron, the other having had the grain refined by thermal treatment. He observed no difference in the rate of diffusion in the two cases.

Experimental. Sheets of 26-gauge ingot iron (0.019-inch in thickness), furnished by the American Rolling Mills Co., were used in the experiments. Strips about one inch wide and two inches long were cut from this and the ends were bent up to assist in holding during the polishing. The lower sides of the strips were then polished and etched in the usual way to prepare them for microscopic examination, after which glass cells, made by cutting from the tops of test tubes, were cemented to the bright upper surfaces. DeKhotinsky medium cement was used for this purpose. The entire assembly is shown in figure 2.

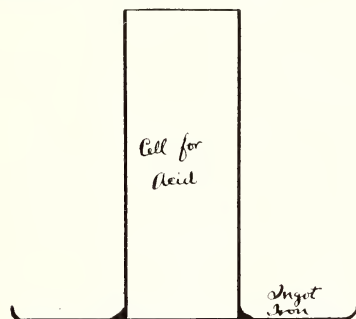


Fig. 2—Acid cell and specimen for diffusion experiments.

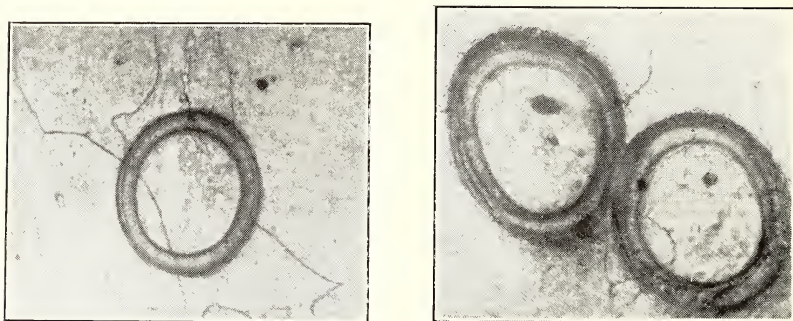
This is somewhat similar to the assembly used by Edwards, except that his experiments were concerned with the effort to measure the diffused hydrogen. Edwards clamped the glass cell to the upper surface of his sheet steel, a wide tube filled with water being fastened to the lower side. In this way he was able to collect the hydrogen which passed through the metal.

The polished and etched lower surfaces of the metal used in the present investigation were lightly smeared with a greasy material. In this way it should be possible to observe, by means of the microscope, any localized liberation of hydrogen which had passed through the iron, microscopic bubbles being formed. Large bubbles were neither expected nor desired. The formation of macroscopic bubbles would make microscopic examination difficult or impossible, at any magnification sufficiently high to reveal the grain structure of the iron, and a substance having a low surface tension was sought, in order that only small bubbles might be retained. At the beginning a number of materials were tried for this purpose but a neutral petrolatum was found to serve as well as any. Approximately normal sulphuric acid was used in the cells and this was allowed to act without heating for several hours, the lightly greased surface being examined from time to time through the microscope.

Bubbles in the petrolatum were observed after about two hours. As the film was quite thin, these bubbles did not grow to any considerable

size but they were plainly visible under magnification. The entire surface was examined and numerous photomicrographs were made. Figures 3 and 4 illustrate typical appearances of the bubbles.

Discussion. If there is any general preference for amorphous grain boundaries, on the part of diffusing dissolved hydrogen, one might expect to observe trains of bubbles following the network of grain boundaries appearing in the sections. No such manifestation was observed. In many cases grain boundaries ran through the areas covered by bub-



Figs. 3 and 4—Gas bubbles from hydrogen diffused through ingot iron. 350x.
(Reduced one-third.)

bles; but too many other bubbles appeared within the meshes of the network to warrant any assumption of this particular mode of travel by diffusing hydrogen.

On the contrary, a large majority of the bubbles were found to be located in such a manner as to cover non-metallic inclusions—microscopic particles of manganese sulphide or of slag. In figure 4, which illustrates the appearance of most of the bubbles, these inclusions are seen as the dark spots appearing within (or at the edge of) bubbles. There is no inclusion of appreciable size appearing under the bubble of figure 3, as was the case with a few others not photographed. But even here is it possible that an inclusion is located barely beneath the exposed surface—so close to this surface that compressed gas could readily burst its way through. The grain structure under this bubble suggests this as the correct explanation. Of course this cannot be stated as a positive conclusion but the large preponderance of bubbles appearing over inclusions, as well as the observed absence of trains of bubbles following the network of grain boundaries, seems to justify the conclusion that the explanation of Edwards is correct: that hydrogen follows no preferential path in its travel through iron or steel, but that at the surfaces bounding inclusions atomic hydrogen collects and forms molecular gas under high pressure, this being responsible for the formation of blisters. It is assumed, in the interpretation of the present experiments, that the major portion of diffusing gas is so uniformly distributed over the surfaces of grain sections, at the surface of liberation, that it finds its way through the thin grease coating without the formation of observable bubbles.

NOTE ON THE LINES OF FORCE IN A PLANE ELECTROSTATIC FIELD CONTAINING TWO CHARGES.

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It is well known that the equations of the lines of force and the equations of the equipotentials in an electrostatic field containing two charges are respectively

$$(1). \quad \frac{e_1(x+1)}{r_1} + \frac{e_2(x-1)}{r_2} = C \qquad (2). \quad \frac{e_1}{r_1} + \frac{e_2}{r_2} = k$$

Charges e_1 and e_2 are located at A $(-1,0)$ and B $(1, 0)$ and are distant r_1 , and r_2 from the point P (x, y) . C and k are arbitrary constants.

$$\text{Thus } r_1 = \sqrt{(x+1)^2 + y^2} \quad \text{and} \quad r_2 = \sqrt{(x-1)^2 + y^2}$$

The direction of the lines of force at any point (x, y) is

$$\frac{dy}{dx} = \frac{y(r_1^3 + r_2^3)}{(x-1)r_1^3 + (x+1)r_2^3}$$

At the point A, r_1 vanishes. At B, r_2 vanishes. Therefore the above derivative becomes indeterminate at both A and B. This might have been expected from the fact that equation (1) is symmetrical with respect to the x -axis and that all lines of force must go through A and B. This means that A and B are singular points for equation (1), but it does not mean that each line of force has singular points. In fact, for each value of C equation (1) represents two lines of force. The author has not found a means of separating (1) into its two branches. In fact, after (1) is cleared of radicals it becomes an equation of the fourth degree in y^2 .

The object of this paper is to obtain formulas which will determine the direction of the lines of force at A and B. To do this we might expand in a Taylor's series about A for instance, and examine the second order terms. This method, while elegant theoretically, presents practical difficulties which are apparently unsurmountable. Therefore the following more elementary method is used.

Equation (1) is cleared of radicals, the origin moved to A and the group of terms of lowest degree set equal to zero. The result is

$$e_1^4 x^4 + e_2^4 (x^2 + y^2)^2 + C^4 (x^2 + y^2)^2 - 2e_1^2 e_2^2 x^2 (x^2 + y^2) - 2C^2 e_1^2 x^2 (x^2 + y^2) - 2C^2 e_2^2 (x^2 + y^2) = 0.$$

This is quadratic in x^2 and in y^2 . Solving as a quadratic in y^2 we get

$$y = \pm \sqrt{\frac{e_1^2 (e_2 \pm C)^2 - (e_2 + C)^2 (e_2 - C)^2}{(e_2 - C)^2 (e_2 + C)^2}}$$

so that the slopes of the lines tangent to (1) at A are

$$(3). \quad \frac{\pm \sqrt{e_1^2 - (e_2 - C)^2}}{e_2 - C}, \quad \frac{\pm \sqrt{e_1^2 - (e_2 + C)^2}}{e_2 + C}$$

Similarly the slopes of the lines tangent to (1) at B are

$$(4). \quad \frac{\pm \sqrt{e_2^2 - (e_1 - C)^2}}{e_1 - C}, \quad \frac{\pm \sqrt{e_2^2 - (e_1 + C)^2}}{e_1 + C}$$

Evidently (1) is symmetrical with respect to the x-axis so that it will be sufficient to consider only the upper half of the curve. Thus the double signs may all be taken positive.

To illustrate the use of these formulas, consider a field in which $e_1 = 4$ and $e_2 = -1$. Suppose a line of force leaves B at right angles to A B. Formulas (3) give

$$\frac{\sqrt{1 - (4 - C)^2}}{4 - C} = \tan 90^\circ \text{ and } \frac{\sqrt{1 - (4 + C)^2}}{4 + C} = \tan 90^\circ. \text{ Whence } C = \pm 4. \text{ Sub-}$$

$$\text{stitute in (4) and get } \frac{\sqrt{16 - (-1 \pm 4)^2}}{-1 \pm 4} \text{ or } \frac{\sqrt{7}}{3} \text{ and } -\frac{3i}{5}.$$

Thus the real branch of this line of force enters A at an angle of about 42° .

These formulas may also be used to determine what must be the relative strength of charges at A and B in order that the field shall contain a certain line of force. Suppose that it is desired to produce a field such that a line of force which leaves A at an angle of 45° shall enter B at the same angle. Formulas (3) and (4) give respectively

$$C = \pm e_2 \pm \frac{e_1}{\sqrt{2}}, \quad C = \pm e_1 \pm \frac{e_2}{\sqrt{2}}.$$

in which the double signs may be chosen independently of each other.

$$\text{Then } \pm e_2 \pm \frac{e_1}{\sqrt{2}} = \pm e_1 \pm \frac{e_2}{\sqrt{2}} \text{ from which } \frac{e_1}{e_2} = \frac{\pm \sqrt{2} \pm 1}{\pm \sqrt{2} \pm 1} = \pm 1, \pm 3 \pm 2\sqrt{2}.$$

On account of squaring, the distinction between $\tan 45^\circ$ and $\tan 135^\circ$ has been lost sight of, but the desired field can be selected by substituting the above results in (3) and (4) and by using physical considerations.

THE AURORA BOREALIS.

ELMER A. SMITH, Secaucus, N. J.

Experiments were conducted in the past four years to determine the reasons for disturbances in the atmosphere and to electrical transmission systems during the aurora borealis. The claims of Prof. R. A. Millikan and Prof. W. Kohlhorster with reference to the alleged discovery made in 1925 that cosmic rays of outer planetary origin penetrate the earth were also investigated.

In order to ascertain these reasons and claims, evidence gathered since 1923 has produced some very interesting data. These data show that the aurora borealis is a direct cause of disturbance to high power transmission systems. High frequency rays and electromagnetic waves emanating or discharged from the aurora are the chief causes for these disturbances.

In order to disclose the results obtained during the experiments, a concise discussion will not be given until a later date. The entire details will then be presented for publication setting forth some very interesting facts.

When these electromagnetic waves penetrate the lower atmosphere, they impinge upon the high voltage transmission lines causing local disturbances in various locations. Very peculiar cases have been observed where such disturbances have either been electromagnetic or of the order of high frequency rays. These rays penetrate many substances. The remarkable values of these rays have been of a wide range of frequencies. In some cases the supposed high frequency radiation was attributed to terrestrial sources, while in others its origin was sought in the atmosphere itself. The plan was to observe the rate at which the instruments would show a deflection and measure the charges according to their intensities.

Location of Experiments. The experiments were conducted in the day and during the aurora borealis and in the evenings, since January, 1923. The most extreme aurora displays occurred on April 14, June 2, September 8, October 15, 1926, and October 11, 1927. The aurora on these dates appeared of a very brilliant and powerful nature. Experiments were conducted in a concrete pipe shaft with lead lining, installed in the river channel, of the Hackensack River, Secaucus, N. J. The pipe shaft was used for the purpose of descending to the river bed with a pair of electroscopes and other sensitive instruments. A wooden float was used for conveying the instruments to the pipe shaft for the purpose of detecting any delicate or feeble charges therein.

Determination of Penetrating Charges. Two electroscopes were carefully lowered into the pipe shaft each time to determine the nature and quantity of the charges. It was discovered that these charges con-

sist of extraordinary rays of a very short wave length, of a very penetrating nature, and electromagnetic waves. These hard rays and electromagnetic waves emanate, or are thrown off from the brilliant aurora streamers and scattered into space.

The electroscopes showed that current charges were circulating in the entire length of the enclosed pipe shaft and in the surrounding salt sea water. The concrete pipe shaft $3\frac{1}{2}$ feet in diameter contained a heavy lead-lined concrete cover at the entrance above the water. The river bed was a distance of 103 feet below the water surface at this location in the river channel.

With the observed readings and numerical coefficients a sum of figures is being prepared. This sum will consist of recorded and calculated values. The readings increase gradually with the depths showing the higher values of penetrating rays and current charges are distributed or scattered about the river bed. This also reveals that ordinary sea water is of a higher density than sweet water. The sea water is more susceptible to electrical charges due to the salt contained therein.

It has recently been observed that the values of these aurora charges are not of any limited quantity, but vary more or less according to the surrounding atmospheric conditions and amount of solar changes. The higher radiation values appear during the spring and autumn seasons.

Penetrating Power of the Aurora Rays. According to recent investigations the highest readings or maximum values of these charges are within the area of water explored. The absorption coefficients are very high in the atmosphere and are equivalent in absorbing power to about 28 feet of water. These high frequency aurora rays coming into the earth possess a penetrating power capable of piercing 103 feet plus 28 which would equal 131 feet of salt water before being completely absorbed. These rays therefore are much harder than any known rays and are capable of penetrating the hardest material substance.

The most penetrating X-rays in commercial use today cannot pass through a half inch of lead whereas these rays can penetrate nearly 13 feet of pure lead. From these experiments it can be well assumed that there is a region of frequencies, as far up above the X-ray frequencies, as are the discovered rays above the frequencies of light waves. However, according to our present day knowledge of physics, these aurora rays are of a high frequency range.

These aurora rays and electromagnetic waves originate from solar radiation. The hardest rays that we are fairly well acquainted with at the present time are the gamma rays of radium and thorium. These hard rays are produced by nuclear transformation within atoms, that is, they are produced by the change of one atom over into another atom or by the birth of a new type of atom.

Since the energy of the nuclear change corresponds to the formation of ordinary helium out of hydrogen the corresponding frequencies were prepared and found to correspond to the known highest frequency rays which were obtained during these experiments from 1923 to 1927 inclusive. In order to compute these frequencies it was necessary to formulate their ranges and calculate them by standard methods used in the

X-ray and gamma ray field. These newly discovered rays have been found to fit on at the top of the well known spectrum and now extend it into the regions unexplored.

Since the atmosphere contains a certain percentage of moisture some of the penetrating charges are absorbed before reaching the river. The rest of the charges are scattered about the earth extending to the river bed which happens to carry them more uniformly in all directions.

It is now definitely known that the aurora is the real cause for creating disturbances in the atmosphere. Since these very delicate charges have been carefully measured interesting data and other information will soon be available.

From experiments carefully conducted in and under the Hackensack River, it was observed that high frequency rays emitted from the aurora borealis impinge upon the earth according to the Compton effect. These high frequency rays are transformed partially into soft scattered rays and into electromagnetic waves. These latter electromagnetic waves travel in all directions. These transformations are enormously more energetic than are those taking place in any radioactive changes which we know anything about.

Conclusions. The surprising results of these investigations are of considerable interest to scientists. They will learn of some of the most interesting facts in conjunction with an important discovery which offers proof that these rays are extremely energetic. It is hardly believable to human intelligence, that such energetic rays and powerful electromagnetic waves are in force during the aurora. It is a discovery of considerable importance and offers possibilities of brighter views into the principles pertaining to astrophysics. It also offers a clear conception of terrestrial disturbances to high voltage transmission, telegraph and radio systems. Emphasis is strongly based upon the knowledge gathered from evidence through experiments.

What the future has in store no living individual knows. At the present moment there appear to be many possibilities ahead for very interesting applications. This very recent discovery has led to a conception of radiant energy traveling through space, at intervals in all directions. This energy appears to our senses in the order of high frequency rays. It emphasizes the apparent impossibility of scientists unraveling the present stage of development of any single consistent and universally applicable scheme of interpretation. An important point of considerable interest is that these rays can penetrate any solid material substance for a considerable depth.

THE VALIDITY AND INTERPRETATION OF MATHEMATICAL FORMULAS.

WILL E. EDINGTON, Purdue University.

At the last annual meeting at Philadelphia of the American Association for the Advancement of Science an interesting address was given by Dr. J. E. Adams of the University of Kentucky on the subject "Is Education Antiquated?" Dr. Adams carried out his investigations by making a survey of high school pupils in Kentucky and received answers from 5,000 pupils to such questions as: "What were the subjects in which you failed? What subjects would you like taken out of the curriculum, and what subjects would you like to take that you cannot get?" The following is a summary of the results as stated by *Science Service*:

"It was found that mathematics and Latin were responsible for far the greater percentage of the failures. The difficulty and lack of practical application of these subjects made them very unpopular. Algebra, geometry and Latin were wanted out of the curriculum. Of the subjects which the pupils wanted to take and could not get, the girls agreed upon domestic science, French, Spanish, typewriting and bookkeeping, and the boys upon manual training, chemistry, typewriting and bookkeeping."

In a recent issue of *The Terre Haute Star*¹ was printed an editorial entitled "Maximums and Minimums in 'Math.'", in which the writer makes an attack upon the rules requiring students to take any mathematics beyond arithmetic. Despite his also apparent antipathy for Latin, the following extract from his criticism is quoted: "Pupils who show an aptitude and a love for other studies, to them certain to be useful studies, are compelled to put in three or four hours daily on home work on a study which they don't understand, never can understand and which they loathe."

These are two illustrations of a change in sentiment that is taking place concerning mathematics, and doubtless louder complaints will be heard in the future, for the heavy scholarship mortality rate among engineering students in American universities can be traced in part to the failure of so many students to pass their mathematics courses. This is shown by a report² of a committee of The Society for the Promotion of Engineering Education which states that judging from the past results only about 30 per cent of an entering Freshman class can be expected to complete the engineering courses in the prescribed four years.

The question then is: What are the mathematics teachers going to do about it? Certainly the question is not easily answered and this dis-

¹ *Terre Haute Star*, August 31, 1927.

² *Journal of Engineering Education*, September, 1926, pp. 121-127.

"*Proc. Ind. Acad. Sci.*, vol. 37, 1927 (1928)."

cussion will be confined to offering a few suggestions to college instructors which it is hoped will help them to make mathematics more interesting and intelligible to college students.

One of the tendencies in mathematics teaching is to reduce laws and processes to formulas. The student learns rules and mechanical ways for solving certain type problems and generally deludes himself into believing that successful manipulation of these formulas constitutes a knowledge of mathematics. Certainly this constitutes the path of least resistance for both student and instructor. However, it is obvious that a mere manipulation of formulas does not imply any real, fundamental knowledge of the subject any more than the manipulation of the controls of an automobile implies that one knows anything about their construction and theory. In other words, the student works with formulas about whose validity and interpretation he knows little or nothing. And this criticism need not be confined to class room students for it applies equally well to many hand-book users. One reason for this state of affairs can be charged to the textbooks which are for the most part written from the standpoint of abstract mathematics, from the classical standpoint.

The formula in mathematics represents the condensation of a more or less generalized process into a few symbols, but these symbols may be open to many interpretations. It has been well said that one gets no more out of a thing than one puts into it, but frequently a formula may have numerous interpretations. The sentence: "St. Clair St. is a st. st." with *Saint*, *street* and *straight* all represented by the abbreviation *st.*, illustrates how the same symbol has a number of different interpretations. Likewise a mathematical formula may have numerous interpretations as for example the integral $\int x^n dx$ which has an infinite number of interpretations although so far only a few have any practical value. As a special case the integral $\int_a^b x^3 dx$ may represent the area under the curve $y=x^3$ between the limits a and b , or it may represent the first moment with respect to the y -axis of a part of the area under the parabola $y=x^2$, or it may represent the second moment or moment of inertia of the area under a part of the straight line $y=x$. And in curve fitting for statistical purposes this same integral might represent third, fourth and higher moments.

Again the integral $\int x^3 dx$ could be interpreted as a line integral with the x -axis as the path of integration, or it might be considered as a line integral $\int x^n y dx$ where the integration is along the path $y=x^{3-n}$. Certainly this simple integral shows the importance of interpretation, for the mere abstract integration is very easy.

The integration of the above gives $x^4/4$ between the limits a and b with the final result $(a^4 - b^4)/4$. What does this mean? Few students ever see that if one writes $y=x^4/4$, where y stands for the area, first moment, moment of inertia, or whatever interpretation is put on the

integral, the value of the integral is found as the difference of two ordinates. That is, one evaluates the integral as the difference of two ordinates but interprets the results as units of area or something else, just as one reads mere scaled units on a thermometer but interprets the reading as temperature.

The preceding results clearly show the necessity of using extreme care in interpreting a formula. Mathematical physics has numerous formulas of broad application whose interpretation depends upon the particular branch of physics in which the formula is applied. Thus, if the divergence equals zero at a given point, it implies in heat no increase or loss of heat at that point, in electricity no change in flux at the point, and in liquids incompressibility. Likewise if the curl of a system of forces is zero over a field, then the system of forces is a conservative system over that field, or if applied to motion, the motion is irrotational. As an abstract relation, if the curl of a function is zero for a given region the line integral is independent of the path in the region, and if the curl for a differential equation of the form $Mdx + Ndy = 0$ is zero, the differential equation is exact.

What has all this to do with making mathematics more intelligible to students? It means that teachers of mathematics must attempt where ever possible to interpret formulas in terms of every-day uses or physical results. More emphasis must be put on the interpretation of the formula and less on the mechanics of solutions.

As to the validity of formulas, it is easy to find formulas that are valid only under certain conditions. Thus, for example, the formula

for fluid pressure is frequently given as $P = w \int xy \, dx$, but this formula is

valid provided the origin is chosen at the surface of the fluid, which is not always the most advantageous. Accordingly, the best way to present the method of calculating fluid pressure is to build the formula for the problem at hand using only the physics of the problem as a guide. Many other such illustrations could be given, but only one more will be cited, namely the well known statistical formula for the computation of the standard deviation of a sum. Frequently this formula is used without giving any thought to the fact that its validity depends on a large number of measurements, and it is applied to a small number of items with the results deduced consequently being questionable. This same statement can be made concerning the use of other formulas in statistics. Some of the formulas of statistics are derived from the properties of the symmetrical probability curve and hence are really only valid when the data to which they are applied are symmetrical or only moderately skewed. This fact is frequently overlooked. The application of a formula implies the validity of its use, and the teacher and student must observe and emphasize this phase of its use. In other words the formula must not become a mere mathematical abstraction but a vital, working process whose derivation is clearly understood and the assumptions underlying it must also be clearly understood. Textbooks must be written with this aim in view and teachers of mathematics in the future must have a broader preparation in physics and chemistry.

The beauty of pure mathematics is not lost, but rather enhanced,

by the fact that, while it does not depend on the physical world for an interpretation, it may be possible to interpret it in terms of the practical world in which one lives. The very fact that nearly all of high school mathematics and much of college mathematics is reduced, so it seems to the student, to the manipulation of oftentimes meaningless formulas which are merely remembered and used blindly by the student, without any connections with his past experiences, makes the subject seem mysterious, fearful, uninspiring and difficult. Of course references are frequently made to applications and occasionally a simple application is discussed in textbooks, but the application side of formulas is generally abstract, analytical or geometrical, and superficial so far as the experiences of the student are concerned. The application side of mathematics should be developed from the very beginning and the student must be made to feel and realize that he is taking mathematics for more than the cultural development it may give him. This attitude implies no compromise on the value of pure abstract mathematics, for its value is just as great as most of the other subjects in the curriculum. Neither should the mathematics courses be reduced to mere application courses. The great German mathematician Felix Klein has well expressed the ideal which should govern mathematical teaching in the following statement:

"First as concerns the *success* of teaching mathematics. No instruction in the high school is as difficult as that of mathematics, since the large majority of students are at first decidedly disinclined to be harnessed in the rigid framework of logical conclusions. The interest of young people is won much more easily, if sense-objects are made the starting point and the transition to abstract formulation is brought about gradually. For this reason it is psychologically quite correct to follow this course.

"No less to be recommended is this course if we inquire into the essential purpose of mathematical instruction. Formerly it was too exclusively held that this purpose is to sharpen the understanding. Surely another important end is to implant in the student the conviction that *correct thinking based on true premises secures mastery over the world*. To accomplish this the outer world must receive its share of attention from the very beginning.

"Doubtless this is true but there is a danger which needs pointing out. It is as in the case of language teaching where the modern tendency is to secure in addition to grammar also an understanding of the authors. The danger lies in grammar being completely set aside leaving the subject without its indispensable solid basis. Just so in the teaching of mathematics it is possible to accumulate interesting applications to such an extent as to stunt the essential logical development. This should in no wise be permitted, for thus the kernel of the whole matter is lost. Therefore: We do want throughout a quickening of mathematical instruction by the introduction of applications, but we do not want that the pendulum, which in former decades may have inclined too much toward the abstract side, should now swing to the other extreme; we would rather pursue the proper middle course."³

³Memorabilia Mathematica, Moritz, p. 77.

TWO NEW NAVIGATION INSTRUMENTS.

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In using an ordinary sextant for the measurement of altitudes of the sun or stars it is necessary to see a good natural horizon in the telescope, the image of the sun being brought to tangency with it. Where a natural horizon cannot be seen a liquid surface is used from which light is reflected to give a second image which is brought to tangency with the first one.

When one is high above the surface, as in the case of an aviator, the horizon becomes more and more distant and less and less distinct and if the visibility is not of the best, is lost altogether, especially in a telescope. The same result is found if there is much smoke, haze or fog even if the observer is on the surface.

It has become desirable therefore to have an instrument which will measure altitudes accurately and in which one need not see the horizon at all, and need not use a liquid surface to get the second image.

A number of such instruments have been produced, in some a horizontal position being indicated by a level bubble, an image of which is reflected into the field of view of the telescope. In others a rotating gyroscopic mirror is used which either assumes a horizontal position or has a small precessional motion about such position. In either one it is necessary for the observer to watch two images and bring them together at a certain point in the field. One image changes its position with any slight change of the observer, or with any change in his motion, and the other with any movement of the index of the instrument, all of which is undesirable and makes for inaccuracy and loss of time.

In the instrument here described this is not true, both images being reflected from the same mirror and moving the same way at the same time. The mirror is a rotating gyroscope top, driven by the observer blowing through a small rubber tube, the air striking the rim of the mirror horizontally at diametrically opposite points. The rest of the instrument consists of two tubes, an index and a graduated scale. The telescope tube is mounted so that it moves with the index and always points into the mirror. The second tube is mounted on the opposite side of the mirror and moves about the same center as the telescope and exactly the same amount, but in an opposite direction. This tube is of smaller size than the telescope and has a lens at the lower end. The upper end is half covered and is at the focus of the lens. The light from the half covered end will then emerge from the lens in a parallel beam, fall on the mirror and if the instrument is held about horizontal, will enter the telescope, the observer seeing a field that is half light and half dark exactly as the natural horizon is seen. This will be true whether the angle of elevation of the tube is great or small.

The telescope lens being larger, will not be entirely obstructed by the horizon tube and light coming from any object in the same direction that the horizon tube points will be reflected from the mirror exactly as the first beam and an image of such object will be formed in the field of the telescope. Any deviation of the mirror from level will change the position of both objects equally and if one object be the sun and it is placed tangent to the horizon line, it will remain so. If the instrument is held approximately level and the index moved to about the altitude of the sun, the telescope then assumes an equal angle to the plane of the mirror (horizontal), the horizon tube assumes the same angle on the other side of the mirror and the observer sees both his horizon mark and the sun in the field, a slight change in the index bringing the solar image into tangency with the horizon, the index reading the altitude directly.

With a small amount of light reflected into the horizon tube at night, the horizon is as easily visible as in the daytime and altitudes of stars can be obtained with great ease. This is a great advantage as stars in different directions can be observed one after another rapidly, each one giving rise to a line of position on the earth's surface and all intersecting at the position of the observer. In the daytime it is necessary to wait till the direction of the sun has changed enough to give two lines that will intersect at a favorable angle, two or three hours at least.

At the present time observations of stars cannot be made at sea except occasionally, the night horizon not being plainly enough seen, nor can observations of the sun be made when the air is smoky or foggy, even though the sun may be distinctly visible. This instrument would allow altitudes to be secured at any time the air was clear enough to see the celestial body. There is never any correction for dip of the horizon, on land, sea or in the air.

In the determination of latitude and longitude by the sextant, the usual procedure is to measure the altitude of the sun or star at a certain time. This time gives us the hour angle of the sun. Using this as one known quantity we can assume a latitude and longitude which we believe to be approximately correct and from these quantities solve the spherical triangle whose vertices are the pole, the zenith and the object observed, the quantity sought being its altitude, which is then compared with the altitude just measured, the difference giving a correction to the assumed latitude and longitude.

In the solution of this triangle it is necessary to use a table of log cosines and one of log haversines and natural haversines. The actual computation consists of finding the log cos of the latitude, the log cos of the declination of the body observed, the log hav of the hour angle, and adding the three together. The natural hav corresponding to this number is then looked up in the table, and to it is added the nat. hav of the quantity, (latitude minus declination). The angle corresponding to this function is then found from the table and subtracted from 90° , the result being the altitude sought. The azimuth must be obtained from an azimuth table before the resulting line of position can be plotted on a map.

For the application of navigation methods to aviation it is important that the observations be reduced as quickly as possible. Going at 100 m. per hr. or more, and taking 30 minutes to find the result may give a man a position where he was at the time of the observation but hardly where he is. It is also important that the reduction be made with as little as possible in the way of books and tables.

In order to get more speed in the reduction and to get rid of all logarithmic computation I have devised a mechanical way of making the solution.

The instrument consists of a disk of brass about 14 inches in diameter having the edges graduated in time on the outer edge and in degrees on a circle about an inch inside the edge. Pivoted at the center of this disk is an arm with a vernier on one end by which either of the graduations may be read and having a slot running through the other half, in which a marker slides. This marker consists of a small plate of transparent celluloid with a fine black dot in the center. Upon the surface of the brass plate there is scribed a circle having a diameter exactly one-half the graduated circle on the edge, and passing through the center. There is also a straight edge which slides horizontally across the brass plate having a hinge by which it may be raised out of the way when not in use.

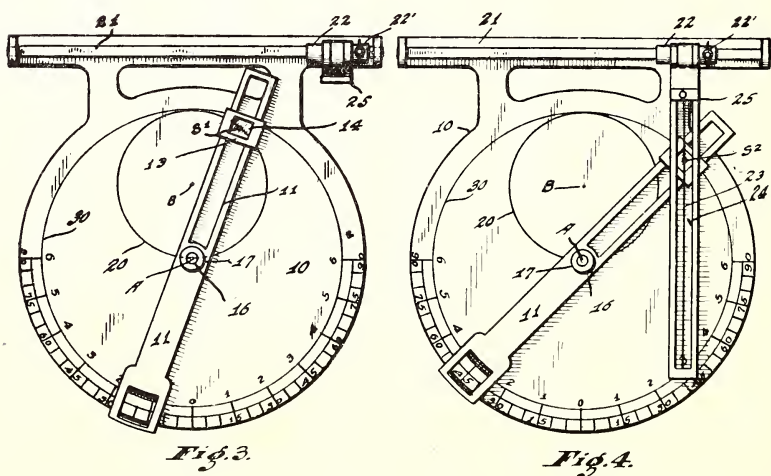
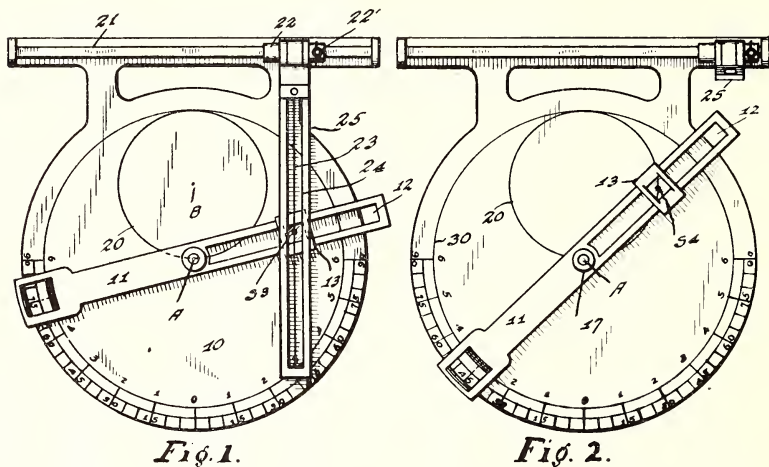
The whole solution depends on the fact that any great circle on a sphere may be made to project into a straight line, and arcs so projected may be measured by a cosine scale along such straight lines.

For an observer outside the celestial sphere in the direction of the north pole, the sphere would be bounded by a great circle, the equator, the pole being a point at the center, and the hour circles being radial lines. When the sun is in the equator it would appear on the boundary of the sphere—at any other time it would appear toward the center, its distance from this point being the cosine of its declination. This point may be determined from the smaller circle scribed on the surface, it having this property: If the pivoted pointer is set at any angle, and the dot in the marker is set on the smaller circle, the dot will be a distance away from the center equal to the cosine of the sun's distance from the equator. The dot will then represent the sun and may be set at the proper hour angle by means of the graduation and vernier.

If now the whole celestial sphere be viewed from any other position in the meridian than the pole, the only change in the apparent position of the sun (dot) is along a vertical line. We therefore set the sliding straight-edge over the dot, knowing that from whatever meridian position we view the sphere the sun will be somewhere in the line. We then set the pointer to the azimuth of the sun as found from an azimuth table. We may now consider that we are looking at the sphere from a point above the zenith, the center being the zenith, the radial lines being vertical circles and the bounding circle the horizon. The sun is in our straight-edge line and is also in the center line of the pointer when it is set for the azimuth. We therefore move the dot till it comes under the straight-edge, move the pointer till the dot comes on the cosine circle, the reading on the vernier being the required altitude. This altitude is then compared with the altitude measured at the time for

which the computation is made, the difference being the amount the observer is away from his assumed position.

This is illustrated in the diagrams, where a latitude of 40° is assumed, a longitude such that the sun has an hour angle of three hours, the declination of the sun being 20° .



Figs. 1-4—Successive stages in the manipulation of a navigation instrument for determining altitudes of celestial bodies, as described in text.

In figure 1, the vernier is set at 20° and the dot is placed on the circle at S. Next the vernier is set at three hours (or 45°) and the straight-edge placed over the dot (fig. 2). The azimuth of the sun is next set off on the vernier and the dot placed under the wire (fig. 3). The straight-edge may now be moved out of the way and the dot brought

over the cosine circle, the vernier reading the corresponding altitude of the sun (fig. 4).

Practically, the larger part of the data can be prepared in advance of the observation. When the time of the observation becomes known the solution need not take over 30 seconds, an azimuth table and ephemeris of the sun being the only tables required. Obviously stars may be used as well as the sun as long as the declinations are not over about 80° . The design of the instrument may be varied somewhat to give greater stability to the straight-edge, make it easier to use in a poor light and to make it possible to find the azimuth without a table.

AGGLUTININ PRODUCTION: TOTAL AMOUNT INJECTED VARIED, DOSAGE AND FREQUENCY OF INJECTIONS CONSTANT.

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It is a general proposition that when certain foreign substances (immunogens) are injected into animals, specific immune bodies are built up.

The resulting antibodies depend upon the nature of the foreign element inoculated. Thus, if bacterial toxins, snake venoms or ferments are introduced in the animal body antitoxins, antivenoms or antiferments result. Likewise, if soluble substances such as blood sera or egg white are inoculated, precipitins are elaborated by the cells of the animal. While if organized cells such as bacterial or red blood cells are injected, agglutinins and lysins may be set forth.

These specific antibodies as well as others undoubtedly play an important rôle in protecting the individual against various toxic substances. So that by this mechanism highly poisonous toxins are rendered harmless by their corresponding antitoxin. Likewise, an individual may be guarded against invasion of pathogenic organisms such as the typhoid bacillus by the elaboration of or the increase of substances which are detrimental to them.

Since this paper deals with agglutinins the discussion will be confined to them. The phenomenon of agglutinins may be defined as the clumping together of cells of plant and animal origin,—organized substances such as bacteria (vegetable), trypanosomes and red blood cells (animal) in suspension.

Agglutinins are the names given to these antibodies which are responsible for the above phenomenon.

Charrin and Roger¹ in 1891 first noticed the characteristic growth of an organism when cultivated in immune serum. Metchnikoff² made a similar observation. Gruber and Durham³ thoroughly studied the agglutination phenomenon and along with Bordet⁴ were the first to reveal the fact that agglutinins had an independent specific action of their own. Widal⁵ showed the practical use of agglutinins in diagnosing typhoid fever.

The demonstration of the presence of agglutinins may be carried out both microscopically and macroscopically. In this work the latter method was resorted to because of its accurateness and simplicity of its manipulation.

¹ Compt. Rend. Soc. de Biol., 1889, 667.

² Ann. d'l' Inst. Pasteur, 1891, 473.

³ Munch. med. Wehn., 1896, 285; Jour. Path. and Bacteriol., 1897, 4, 13; *ibid.*, 1901, 7, 240; Brit. Med. Jour., 1898, 2, 588.

⁴ Ann. de l' Inst. Pasteur, 1895, 9, 462.

⁵ Semaine med., 1896, 259.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

In two previous papers presented before the Academy agglutinin production was described in which the frequency of injections was varied while the dosage and the total amount of the antigen inoculated was constant.⁶ Also the converse of this experiment was discussed, namely, the frequency of injections was constant and the dosage and total amount inoculated was varied.⁷

Of the eight practical variations of these three components an experiment was undertaken in which the total amount of agglutinin injected was varied while the dosage and frequency of the inoculations was constant.

That is, rabbits were injected at daily intervals with 1 cc. for one to ten days and consequently received from 1 to 10 cc. of a typhoid vaccine. This bacterine contained two billion typhoid bacilli per c. cm. killed by heating to 58° c. for one hour.

TABLE I. Showing Titres of Typhoid Agglutinins in Rabbits Injected* Once to Ten Times at Daily Intervals.

No. of Rabbit	No. of Injections	Total No. c.cm. Injected	Titre	Average Titre
1 2	1	1	3000 3000	3,000
3 4	2	2	1500 3000	2,250
5 6	3	3	4000 8000	6,000
7 8	4	4	3000 3000	3,000
9 10	5	5	4000 4000	4,000
11 12	6	6	5000 8000	6,500
13 14	7	7	4000 5000	4,500
15 16	8	8	8000 8000	8,000
17 18	9	9	5000 10000	7,500
19 20	10	10	16500 17000	16,750

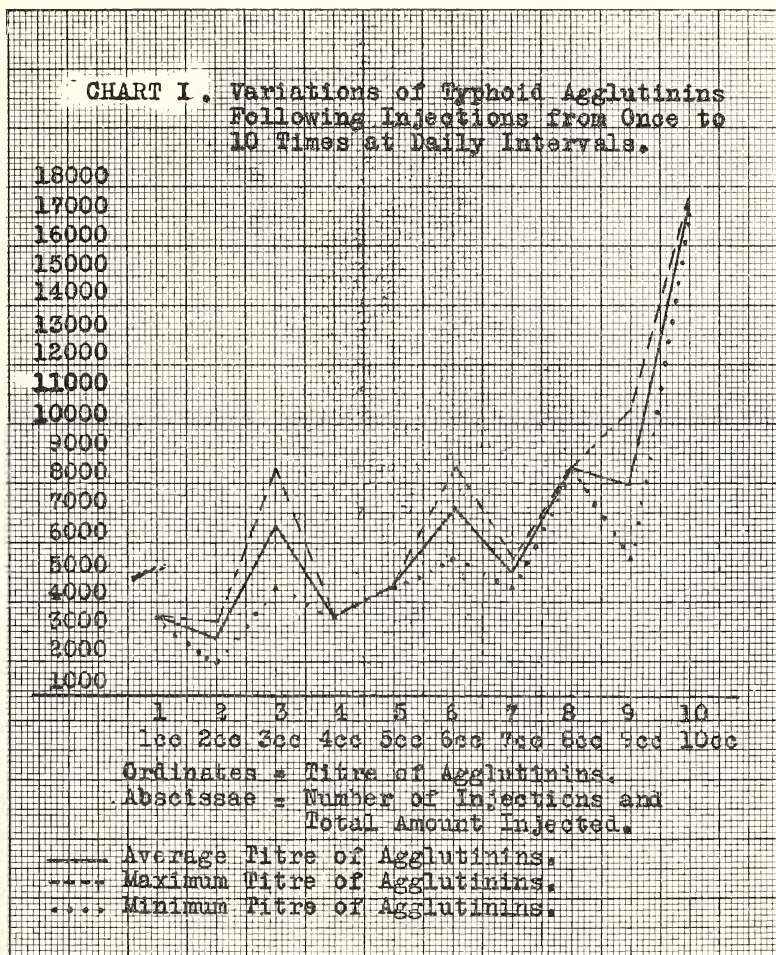
*1 cc. Intravenously.

Rabbits 1 and 2, as will be observed in Table I, received but a single injection and each developed titres of 1-3000. Rabbits 3 and 4 were inoculated once every day for two days; their agglutinin titres were 1,500 and 3,000, respectively, an average of 2,250. Rabbits 5 and 6 were similarly inoculated for three days and their titres were 4,000 and 8,000, respectively, or an average of 6,000. Likewise rabbits 7 and 8 were injected for four days and each showed titres of 3,000. Animals 9 and 10, which were inoculated daily with 1 cc. for five days and con-

⁶ Proc. Ind. Acad. Sci. 1925, (1926) 34, 259.

⁷ Ibid, 1926, (1927) 36, 313.

sequently received a total of 5 cc., each developed agglutinins with titres of 1-4000. Rabbits 11 and 12 were injected on six consecutive days. Their titres were 5,000 and 8,000, respectively, an average of 6,500. While rabbits 13 and 14 injected similarly for seven days had titres of 4,000 and 5,000, or an average of 4,500. Rabbits 15 and 16



injected on eight successive days developed titres of 8,000 each. Rabbits 17 and 18 inoculated for nine days showed titres of 5,000 and 10,000, respectively, an average of 7,500. While rabbits 19 and 20, which were injected consecutively at 24-hour intervals for ten days and received a total amount of 10 cc. of the vaccine, showed a marked increase of agglutinin production with titres of 16,500 and 17,000, respectively, or an average of 16,750.

The minimum, maximum, and average titres of agglutinin development in these animals is shown in Chart I.

An interpretation of these results reveals the fact that typhoid agglutinins of a high potency can be built up in rabbits by inoculating them with small amounts (1 cc.) at daily intervals for a period of days, preferably ten.

Generally speaking, there is an increase in the agglutinin development as the number of days of inoculations are prolonged.

PRESERVATION OF ISOHEMAGGLUTINATING SERUM
WITH PHENOLIZED GLYCEROL.

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In 1920,¹ I reported on the activity of some year-old isohemagglutinating serums that had been preserved by the addition of phenol to the extent of 0.5 per cent, added directly to the serums. The serums in that case were very cloudy in appearance and had distinct sediments. Since that time I have used a mixture of 10 per cent phenol dissolved in glycerol as a preservative, adding the mixture to the extent of 5 per cent, thus making the total percentage of phenol 0.5 per cent as in the earlier use. The serums preserved with the phenolized glycerol remain essentially clear and are free from the sediment seen when the phenol is added directly.

In the early part of this year, 1927, an ampoule of parasthenic serum (group II, Jansky, Moss; A, Landsteiner) and one of antiparasthenic serum (group III, Jansky, Moss; B, Landsteiner) were found in the ice box, bearing a date four years earlier.

In order to see if the serums in the two ampoules still retained their specific actions on the cells of the four different blood groups, after a lapse of four years, fresh parasthenic and antiparasthenic serums were secured and duplicate agglutinations were made with the cells of 50 different persons. These persons were distributed among the four human blood groups as follows:

Sthenic;	group I, Jansky;	group IV, Moss;	O,	Landsteiner; 22
Parasthenic;	group II, Jansky;	group II, Moss;	A,	Landsteiner; 23
Antiparasthenic;	group III, Jansky;	group III, Moss;	B,	Landsteiner; 2
Antisthenic;	group IV, Jansky;	group I, Moss;	AB,	Landsteiner; 3

The two old and new sets of serums gave identical agglutinations with the erythrocytes of these 50 persons. Cells of persons of the sthenic group were not agglutinated by the parasthenic and antiparasthenic serums; cells of persons of the parasthenic group, agglutinated by the antiparasthenic serum, only; cells of persons of the antiparasthenic group, agglutinated by the parasthenic serum, only; and cells of persons of the antisthenic group agglutinated by both the parasthenic and antiparasthenic serums. In none of the 50 instances was there any doubt as to whether the four-year-old serums caused agglutination if the new serums caused it. The size of the clumps formed by the use of the old serums was usually smaller than in the case of the new serums. There was no essential difference between the old and the new serums as to the rapidity of agglutination. There was no indication of

¹ Jour. Amer. Med. Ass. 75, 1002, 1920, October 9.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

non-specific agglutination. The old set of serums was perfectly usable in making the determinations of the blood groups to which persons belong by observing how such persons' erythrocytes agglutinated with the parasthenic and antiparasthenic serums.

Isohemagglutinating serums may be preserved with 5 per cent of a 10 per cent solution of phenol in glycerol, and retain their specific properties for a period of four years. The serums remain essentially normal in appearance.

ANTAEUS—CONTACT WITH THE SOIL.

ROBERT HESSLER, Indianapolis.

Fable, folk-lore, romance and poetry have all contributed their share toward preserving the experiences of the human race in its evolution. Mythology has always shown great fertility when cultivated by the philosopher, but occasionally the naturalist turns a spade to his own satisfaction. Perhaps some day we may reach a clearer understanding of the significance of mythological nomenclature, but until then our deductions even though somewhat fanciful may still give us a glimpse of an underlying truth.

It is a frequent observation among naturalists that the common experiences of mankind may at times be translated into scientific dicta—when sufficient data have accumulated for drawing conclusions. But the important and far greater task is that which concerns itself with the application of scientific information to the welfare of the race. A great question among educationists now is, how to get the individual of average mind, for his own good, to take advantage of the enlightened work of scientists.

But movements, like organisms, are attacked by parasites, and unfortunately the movement of “humanizing” knowledge has already fallen heir to the fate destined for all good things; and the general public is receiving the perverted and distorted facts of science. The wrappers of the breakfast foods, the circulars outlining the menu courses, and the labels for every form of drink present the “scientific” reasons for their use—all in the language and under the seal of “humanized” science.

Moreover, it is recognized by every earnest worker in science that his efforts are vain if no practical use will or can be made of his work and efforts; and he thus clearly admits the necessity of “humanizing” the results of his researches. A single instance in my own experience, however, demonstrates how much patience and time is required before practical results from seemingly obvious truths are secured.

In 1893, before the Indianapolis Woman’s Sanitary Society,¹ I read a paper on the rôle played by infected dust in the production of ill health and disease—particularly in communities where the tobacco-chewing and spitting habit prevailed, in which I insisted that the resulting state of filthiness on sidewalks and streets not only encouraged the catarrhal and tuberculous to add their pathogenic sputum, but also aggravated the nuisance and transformed it into an actual menace to health, giving rise to what is known as the infected dust problem.

Eight years afterward, while engaged in a special study of this infected dust problem and the causation and prevalence of ill health

¹ For a mention of and comments on this paper see the Indianapolis News of July 14, 1893.

and certain forms of diseases, at Logansport, I had the temerity to distribute copies of a pamphlet in advocacy of an anti-spitting ordinance and giving reasons therefor. In reality it was merely a reprint of my paper published in the Monthly Bulletin of the Indiana State Board of Health, for I had already begun a series of papers before our Academy, of which the present paper is a continuation.

At that time I was in correspondence with the late Dr. J. N. Hurty, Secretary of the State Board of Health and Editor of the Monthly Bulletin of the Board. He was a man who had early adopted my ideas and was convinced that the dust factor in the spread of diseases was entitled to earnest consideration. But although in full accord with my theory, he nevertheless advised going slowly in regard to practical measures, emphasizing that "We must take one step at a time, as you very well know. You also know that we cannot arrive at the very top with one bound."

I might add that one result of my effort in regard to clean streets and sidewalks was to arouse the antagonism of a number of the worst chewers and spitters, some of whom "demanded the right to spit where they d—— pleased." Clearly the man who remains silent has the smoothest sailing.

In the light of the above, and at the risk of self-condemnation in my attempt to "humanize" the scientific work on which I have been engaged for nearly 40 years, I shall in this paper present one aspect of the philosophy of The Domestication and Urbanization of Man by drawing a lesson from Greek mythology—the celebrated victory of Hercules over Antaeus, son of Poseidon (Neptune, lord of the sea) and Gaea (goddess of the earth).

The story runs that Antaeus, a famous wrestler of Libya, was invincible so long as he remained in contact with the earth, his mother, for his strength was renewed with every contact with the soil. Hercules, however, discovering the source of the strength of Antaeus, lifted him from his mother-earth, and strangled him in the air.

If we trace for a moment our mythological figure through English literature, we find him appearing in Spenser's *Malegar* (Fairie Queen), whom Prince Arthur was able to conquer by lifting him from the earth. Erasmus Darwin refers to the same figure in his "Economy of Vegetation," and the frequent allusion to a "return to his native air" in English biographies reveals the old belief that the simple-life conditions of youth were conducive to the restoration of health and strength. From many pages of the "Life and Letters of Thomas H. Huxley" we can glean the benefits to be derived from contact with the soil, and in a single page the biographer, although perhaps unintentionally, has contrasted the deleterious consequences of too much artificial life in the city with the salutary effects that attend contact with the soil. (Vol I, page 154.)

But in our own country we scarcely know the significance of the term "native air," although in David Grayson's "Adventures in Friendship" the author catches a glimpse of an old truth when he asserts that "with my feet upon the earth, I am invincible and unconquerable," and "at each step my strength is renewed."

One is here reminded of a full-page nostrum advertisement carried in some newspapers 20 or 25 years ago to the effect that a certain rich man had offered a million dollars for a new stomach. An advertisement suggested the use of a nostrum, but evidently the rich man followed sounder advice, for we find him today playing golf in Florida during the winter, and in summer enjoying the free air of his northern estates, thus proving that also in his case "contact with the soil" means health and longevity.

To understand men like Thoreau and Burroughs and Muir there is need for a proper orientation in regard to the environment of men,—its influence and effect not only upon the physical nature or constitution but also upon the temperament—the psychical nature and mentality, and we should keep in mind the old story of Antaeus retaining vigor and regaining strength.

To further impress this lesson from mythology, romance, poetry, or from the biographies of those who have passed away, one may refer to a shining example of today,—President Coolidge, who takes his vacations "in contact with the soil." On the contrary, when the late President Wilson returned from Europe, where he had been subjected to a terrific mental strain, and then plunged into a stump-speaking tour, taking upon himself the herculean task of seeking to educate his country to the importance of entering the League of Nations, he subjected himself to crowd conditions,—to reactions that have proved fatal to many a public speaker.

The student of domestication and urbanization must feel that had President Wilson, immediately upon his return from Europe, taken a short rest cure with its prime essential, clean air, history undoubtedly would record far different world effects from the outcome of his subsequent western trip than the tragedy which befell the head of the nation.

This idea of "contact with the soil" embodies profound truths which mankind has garnered from long experience; but these truths, in order to be effective for the welfare of the individual in this complex age, must be presented in a scientific manner. Intelligence today will not, and should not, be satisfied with fable and adage, for the impression on the mind today must be clear and distinct.

Man is indissolubly connected with his remote ancestry, and modern scientific aspects contain the reflections of his past. The biological or life history of man begins where the histories of all forms of life begin. Nature is one. The struggle for existence and the survival of the fittest are not mere phrases, but are definite concepts embodied in accepted laws defining the conditions under which life has and continues its being.

The ascent of man from primeval conditions or stages is characterized by a succession of struggles against opposing forces. The antagonisms which man is compelled to meet, to maintain himself and perpetuate the species, are not only those of the struggles with other forms of life, but there are also the cosmic or planetary elements to contend with,—earth, air, fire, water, and the various factors that enter into what is called climate—the myriad results usually referred to as

geological and terrestrial changes, not forgetting "the earth as modified by human action."

In the primitive or savage state man's contact with mother earth was supreme, and he was bound by no law not binding on other organisms. Out of place, he succumbed; in his proper place, he stood an even chance with other organisms. Life in the hunting and fishing stage was very simple, and what we call "health" took care of itself, as it does today among those who "live in contact with the soil."

In the barbarian stage man became more concerned with the survival of himself and his progeny, he began to free himself from dependency of simple natural conditions. His efforts included the making of a domicile, a home for his family, better conditions for his progeny. The cave and hollow tree of the savage were abandoned, and in time his tent became a permanent home, lifted from the ground, a first stage removed from direct contact with the soil.

The advent of the pastoral stage made man less dependent on immediate natural conditions, and although he followed his herds and flocks to good pastures in a movable tent, it was still a contact with the soil. At the same time it was a contact with animals, and the pathologist would here find occasion for much speculation in regard to the evolution of infestations by parasites of many kinds. The modern "milk problem" is complicated by the fact that the milk may pass through many hands before it reaches the consumer.

As a result of the constant shifting of the home during this tent-life stage, leading the herds to fresh pastures, there was no polluting of the water supply for man or beast nor a polluting of the soil. All this comes later. The agricultural stage, however, meant a fixed home, it meant to take care of the growing crop and storing it for the winter season. Living conditions now became better, less precarious, and man for the first time was able to give attention to the aged and to the sick, to those who under simpler life conditions had little chance of surviving the savage or nomadic life struggle. Here again the pathologist can speculate as to the evolution of all sorts of infections, in distinction to infestations, for here we find the origin of a great modern problem, which one might refer to briefly as "rebreathing air."

Domestication has been man's creation and has brought him problems unknown to earlier stages; and when houses come close enough together to form villages which in time become towns and cities, with the advent of the handicraft stage, we meet with the problems of urbanization, a stage in which many a man finds himself far removed from the simple out-door life of the hunter and fisher, of the herdsman and of the agriculturist. This lack of contact with the soil may reach an extreme stage in the case of the dweller in the modern industrial city. Cities, in the past, and still largely so today, are the graveyard of man.

The growth of the city had given rise to all sorts of problems, and there is a series of terms derived from the Latin word for city,—*urbs*. *Urbane* includes the need of conforming to the mores of the city, with all sorts of laws, regulations and ordinances to be obeyed. Yet we are only beginning to recognize the need of obeying the unwritten laws of

nature and her warnings, that primarily man is still an animal, and that contact with the soil, much or little contact, is necessary to survive, both ontogenetically and phylogenetically. It emphasizes again the need of simple life conditions to maintain families, or, in other words, as an antidote to so-called race suicide. Here we can get some valuable ideas from biographies, notably biographies that refer to London conditions.

Urbanity carries with it the idea of polite behavior and polite learning,—academic life and art; but there also enters the idea of cloister life,—studying the heavens and neglecting the soil under foot. The path of civilization from the cave and tree of the savage to the lecture room of the student and the laboratory of the modern scientist is indeed strewn with the skeletons resulting from environmental antagonisms.

Every change of environment has placed upon man new burdens, and the extent to which he has been able to overcome them successfully has determined his degree of civilization. Adaptation to city life is carried on at an enormous loss. Adjustment to indoor life conditions may be impossible to the unadapted. The modern city requires men to fill all sorts of positions, from the lowest to the highest—from those where little mentality is needed to those demanding the brain of the superman. Under city conditions vocations vary from those where men are confined indoors and lead a sedentary life, to those with more or less active life out of doors. But all are wholly dependent on life conditions that are artificial,—on food that has passed through many hands, on water that has been brought in from a distance, on air that has perhaps been breathed over and over, and on shelter that differs widely from that of primitive man. The climate with which savage man had to contend was the natural climate; but today so-called civilized man in our latitude lives in an artificial climate for half the year, and therefore it is no wonder that our city children are at times referred to as hothouse products, lacking all proper contact with the soil. How do they fare?

The chief problems of man today are those growing out of domestication and urbanization. All the arts and sciences now make their major contributions toward furthering the evolution of the home and the city. That is what is meant by civilization. But in some aspects man has not met the issue of civilization with the same degree of success. Nations still settle their differences by the final appeal to the sword. The League of Peace is much talked and written about, but it may be difficult to find a good friend of the man who most concerned himself with such a league. Although science, as represented by the chemist, the bacteriologist, the immunologist, and many others, is tremendously engaged in the laboratory and clinic in seeking to discover new "cures" and, in general, in developing new methods to make or to keep us well, whole and sound, nevertheless hospitals are multiplying as never before, and ill health has become a constant attendant on the lives of the great majority of men and women, and alas, even of children.

The alleged lengthening of the span of life does not apply, unfortunately, to the lives of many whose longevity and mentality should be prolonged,—too many of our brightest and best still die prematurely;

it seems, shall one add, that hospitals and asylums are developed with a view of prolonging the lives of the defectives, dependents and delinquents. The anthropologist, the biologist, the eugenist and the humanitarian may agree with Dean Inge that too many lives are "saved" that are not worth saving, and that the misery of many is prolonged through excessive hospital and misguided asylum care. But for conscientious physicians, who of all men have the best insight, to discuss such matters openly would mean professional suicide.

Physicians speak of the great increase in morbidity and mortality of "degenerative diseases," of the great loss of men at an age when they would be at their best and when their advice and counsel would be of great value to the young and to the nation. It is rare and exceptional for an occupant of the White House to reach the proverbial three score and ten. Even more tragic, because intimately affecting so large a number, is the death of physicians, men who might be assumed to know the underlying factors and to take measures to avoid premature death.

What have we lost or what have we failed to acquire in the development of civilization that so places man's health in constant jeopardy? We are certainly spending a lot of time and money on matters pertaining to health and disease. Is it perhaps that the efforts are directed along lines no longer fruitful, perhaps antiquated? It may be that the time has come for a re-orientation. Certainly a new view must be taken of man's health and how to keep it, and the problems growing out of his multifarious attempts to "keep fit."

The proverbial sound body may keep fit for a long time on coming in contact with unsanitary city conditions, and some things we may do to maintain "keeping fit" may have only a remote if any actual effect. But with advancing years, the only real remedy is offsetting—contact with the soil.

One thing is certain. Under domestication and urbanization man has steadily moved farther and farther away from the conditions where contact with the soil was easy. Nature no longer supplies man in his complex environment with pure food, good water and clean air; and it is everywhere evident that man is not providing these under the former simple-life conditions.

Although we may drink good water while eating food of doubtful constitution, it may be under air conditions that are wholly abnormal. The problem of good water was one that cities had to master early, and the question of good proper food is receiving great and constant attention, but what is a proper dietary is a question that has not been settled,—the man who follows a text-book on food and diet that is five or ten years old would be pronounced an old fogey. Yet to the man leading the simple outdoor life the question of food and feeding usually resolves itself simply into the question of getting enough to eat, on a par with the rest of creation.

As just indicated, the question of good water and of good food have received much attention, technical problems that go with such matters being gradually mastered; but so far, man has utterly failed to make adequate provisions for pure air. Fresh air may not at all be pure

air, and in cities it is not clean air. Even in the case of hospitals the surroundings are usually such as to preclude even the suggestion that the question of clean air had been given proper consideration, much less first consideration. Eating and drinking occur at fairly regular intervals, and proper care to get food and drink can be exercised as may be deemed best, but the process of breathing is continuous, inhalation and exhalation occurring every minute. The weight of the air we use far outweighs what we eat and drink.

Formerly the nostrum maker had all sorts of remedies and cures for the ills attending the use of food and drink, but today he seems to find it more profitable to advertise nostrums for affections and conditions of the respiratory system. Halitosis is an old term for bad breath, but how many now using the word ask the where, when and why?

How very slow has been the appreciation of the value of good, clean or pure air to man. Until recently it has been almost entirely neglected. Whenever the question of "fresh air" has come to the front in public discussion there usually has been some motive other than human welfare that has actuated the agitation. The value of and clamor for clean air in cities finds a ready response from merchants, who desire conditions that will longer preserve delicate fabrics and perishable goods,—unsold merchandise. There is also a demand for sootless air to avoid the expense of cleaning up, and this cleaning process extends all the way from your dirty neck and collar to the front of tall buildings in the heart of the city and to monuments perhaps topped by a flag so dirty that it is almost unrecognizable as our proud starry banner. The expense of cleaning up comes either directly out of our pocket, or is paid indirectly through increased taxes.

We are taxed tremendously to keep up our public school system, where efforts are made in regard to sanitation and hygiene. School children receive extra attention, teeth and throat are looked after by the teacher, and tonsils and adenoids are given attention. But the general city air, the air of public conveyances and the polluted air of factory environs, has not yet come into its own.

The ancients knew nothing of microbes, although Lucretius mentions the motes in the air. Today we are only beginning to understand the importance of the defensive system of the body and its rôle in protecting us from our microscopic enemies. The enormous scrofulous swellings seen in the highly unsanitary cities of Europe a hundred and more years ago have practically disappeared under sanitation, but additional knowledge, skill and attention will be required on the part of the sanitary engineer to change the conditions that favor enlarged tonsils and adenoids, and other throat and nose affections that now call for surgical operations.

It is essential that clean air be provided for the worker upon whose efficiency our whole social structure, indeed, our whole civilization, depends. Here and there a feeble voice is heard. Smoky air and dusty air are twin evils. The agitation against spitting in public places has made an impress; in the larger cities tobacco juice spitting on floors and sidewalks is now taboo, but emptying cuspidors into gutters may still be tolerated. Filthy gutters and filthy streets are still everywhere in

evidence. Pulverized filth arises as dust, and asphalted pavements may be swept clean by speeding automobiles and street cars. Dried and pulverized gutter filth arises as infected dust, a veritable poison to many. Cinder dust, only too often found on streets, is gritty and, where it carries infection, leads both to acute inflammation and to the ultimate formation of scar tissue; sclerosis may extend all the way from the skin to the internal organs and arteries, with impairment of normal physiological functioning. We supply the treatment for colds, catarrhs and the like, and there are countless assumed remedies for our Triad of American Diseases (catarrh, dyspepsia and nervous prostration), but prevention is still an open question.

We test the efficiency of the worker in the factories under improper and proper conditions of lighting, and we have worked out, perhaps motivated by lighting systems companies, schemes that increase the efficiency of the worker by giving him the proper and adequate light for his work. But so far tests on a comprehensive scale have not been made to determine the rôle played by the conditions under which he must breathe, neither quantitatively nor qualitatively, although, through the work of industrial commissions here and there, factory "airs" have been tested for pernicious contents incident to the particular industry.

It is rather anomalous that the school books on so-called Physiology and Hygiene should put so much stress on the matter of food, and be practically silent in regard to the air that we must consume to oxidize the food. We eat about three or four pounds of food per day, while at the same time we take in about 30 pounds of air,—air often of doubtful constitution. And as to the motes in the air, a bright beam of light, as in an illy ventilated movie, reveals them in countless numbers.

Until only a few years ago the term environment was rarely seen in the index of educational books, although educational psychologists had been using it for some time. It is likewise a rare term in the index of medical books, although during the last few years there has been an increasing use of the term in medical journals. Here is an interesting little subject for study by the bibliographer.

Frequently I have called attention to the great value of the study of biography in obtaining knowledge in regard to the influence of good and bad air conditions and effects,¹ and the need of offsetting indoor life by life in the open. The biographer must give more attention to the environment of his subject.

Just 20 years ago I presented before this academy a paper entitled "The Influence of Environment of Man," and the last two paragraphs of the abstract that appeared in the Proceedings for 1907 are as follows:

"Reaction to environment varies greatly, from a feeling of health to ill health and disease. Pain is to be regarded as a warning from nature and plays an important rôle in the process of adaptation to environment. Some strains or individuals are wholly unadapted to city life with its manifold disease-producing conditions. Many disease-producing conditions have been eliminated from city life today, others are more active than ever, notably the impure air factor.

¹ See for instance my paper on "Biography and the Influence of Environment," in the Proceedings of our Academy for 1908.

"A study of simple country conditions, or village conditions, or town and small city conditions may shed much light on the complex city life. Much of the ill health and disease of the large city is preventable, and the lives of many can be lengthened. The erection of more hospitals, as ordinarily conducted, is not a remedy for correcting the evils of city environment; the environmental influences are themselves largely to be altered. Much depends on education and there is urgent need for an institution that will take up the study of factors operative today." (The factors referred to are those operative in the process of the domestication and urbanization of man.)

In conclusion, let me again refer to my mythological inspiration, the story of the tragic end of Antaeus. Wrestling with the powerful Hercules he was invincible as long as he remained in contact with the earth; but he was vulnerable, and the weak spot in his defense was discovered by his enemy who separated him from the earth and strangled him in the air.

The dirty air of our cities is full of microbes constantly ready to attack those who lose contact with the soil. Some one has said that we live in a sea of microbes. Our defenses, and especially our lymphatic system, may be readily overworked, and if we do not constantly renew our strength by contact with the soil we shall fall victims to the very air we breathe—literally strangled in the air.

Until science has made sufficient strides to meet the problems above indicated, and until the sanitary engineer has convinced the people of the importance of clean air in the cities, there remains but one solution; the individual must regard his welfare from the viewpoint of the air he breathes. Clean air is the meaning of Antaeus—contact with the Soil.

THE LONGEVITY AND SWIMMING ABILITY OF SPERMATOOA.

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Abstract. The spermatozoa and eggs of most marine invertebrates are shed into the sea water, where fertilization and development take place. The vigor with which the spermatozoa swim varies greatly in different species. Some scarcely move perceptibly, while others are extremely active.

While studying the longevity and vitality of unfertilized gametes, including the eggs and spermatozoa of several species of annelids, molluscs, and echinoderms, the writers undertook to learn how far a spermatozoid would swim when unassisted by currents. Gemmill, experimenting upon sea-urchin spermatozoa, came to the conclusion that they may swim a distance of seven inches in an open dish, but only a few centimeters if enclosed in capillary tubes.

After numerous trial experiments we selected glass tubes approximately one inch in diameter in place of capillary tubes. Without going into detail in a description of the apparatus used, it may be sufficient to say that we were able to introduce sperm at one end of the experimental tubes and unfertilized eggs at the other. By a series of experiments, using tubes of various lengths, we learned how far spermatozoa would swim to fertilize eggs so introduced.

The spermatozoa of the sea-urchin (*Arbacia*) were able to swim 29½ centimeters in five and one-half hours. The spermatozoa of *Cumingia*, (a lamellibranch mollusc) performed at the same rate. Some millions of spermatozoa were introduced and about 20 spermatozoa of each species swam the distance in the time specified. The spermatozoa of *Hydroides* (an annelid) were found to be inactive and swam very little except when stimulated by the proximity of eggs whose secretions excite them to a certain activity, but without which they would not swim.

Spermatozoa which fail to fertilize eggs usually die within seven hours from the time they are shed. They often become inactive after five hours, so that the results given above represent the approximate limit of their swimming ability.

The unfertilized eggs of these same species live somewhat longer than the spermatozoa. Thus, unfertilized eggs of *Cumingia* live from six to 22 hours; those of *Hydroides* from eight to 38 hours; those of *Nereis* from six to 24 hours; those of chiton from eight to 40 hours, and those of *Arbacia* live from 26 to 48 hours.

In conclusion it may be said that spermatozoa shed into water die within a few hours if they fail to meet an egg. The unfertilized eggs, on the other hand, live for longer periods, which vary with the species.

A STUDY OF SCHOOLROOM VENTILATION INVOLVING A COMPARISON OF TWO TYPES OF HEATING AND VENTILATING PLANTS.

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The purpose of this study is to determine the relative value of two distinctly different types of schoolroom ventilating systems.

For a number of years school authorities have been concerned with the physical surroundings of children under their care and supervision. The National Education Association has had a sub-committee on ventilation. They found there has been a change in the point of view of educators in general on this question, from the attitude which considered only the needs of frail children to a realization that all children in all schools must have provisions for better air conditions in order to insure good health. The story of the boy who brought his frail undernourished friend to the open-air school doctor with the query, "Say, doctor, how sick has a feller got to be to get in this here school?", continues to be a challenge.

The New York State Commission on Ventilation reported in 1922 the following results of experiments extending over a long period and checked by many tests.

1. Ordinary effects of stale air have nothing to do with the oxygen or carbon dioxide content but vitiated air has a distinct influence upon appetite and the inclination to physical work.

2. The factors in ventilation which produce bad effects are over-heating, excessive humidity and lack of air movement.

3. Comparatively slight degrees of over-heating produce derangements in the circulatory system, lowers efficiency and tend to promote susceptibility to respiratory infection.

Various methods of ventilation were tested, including window and fan ventilation, humidification and re-circulated air with the following results:

1. Modified window ventilation alone without suitable means of exhaust was unsatisfactory, but with provisions for outlet through gravity ducts was found satisfactory.

2. Ventilation by plenum fans with gravity exhaust was satisfactory from the standpoint of aeration, but this system necessitates a higher temperature and provides, as well, relatively constant temperature.

3. Re-circulated air was found economical and harmless to health but the humidity necessary produced discomfort and the air was stale.

Two experiments in New York City, one lasting eight weeks and the other 12 weeks made to test the relative merits of fan and window ventilation showed a definite excess of respiratory diseases among chil-

dren in the fan ventilated room. The warmer fan ventilated room averaged 18 per cent more absences due to respiratory illness and 70 per cent more respiratory illness among the children in attendance. The study indicated that the slightly higher temperature and more uniform air conditions of the fan ventilated room tend to promote susceptibility to respiratory disease. It found in brief, the most harmful air to be over-heated air, that when a great volume of air is pumped through a room by mechanical measure it must be heated beyond a point compatible with health or comfort in order to ensure an even temperature and avoid drafts, and it recommended for schools and similar buildings a system of open windows protected by deflectors to send the cool air upward, and a gravity exhaust system to carry out the hot and vitiated air. It concluded, "and however simple or complex an apparatus may be installed for air conditioning, a constant and intelligent vigilance in regard to operation and over-heating is the price of health and comfort."

Schools generally are indifferent to room temperature, in only 38 per cent of the schoolrooms visited by the New York Commission were there thermometers. Trouble lies in the belief that ventilation is automatic. No system can be automatic, neither can the average janitor supervise the ventilation in every room.

"A study of the ventilation practices in ninety-six cities distributed in thirty-one states recently revealed that in 79 per cent of the representative schools of these cities mechanical systems of ventilation have been installed. However, it was further discovered that in many of the schools the ventilating systems were used merely as adjuncts to heating. There is an investment of millions of dollars in idle split-plenum-fan ventilation equipment in certain cities of the United States."

In the January, 1926, number of the American Journal of Public Health we find that the construction costs of fan systems with supply ducts exceeds the window systems from 22 to 85 per cent in cost of construction. Then since the use of the fan system at once implies over-heating of enormous volumes of air which are almost immediately blown out through the roof of the school houses, it must be obvious that this method costs more for operation than the window method.

Yet we find more than half the states of the United States requiring by law the fan type of system. This traces its ancestry to the last decades of the 19th Century when German and British investigators set up the theory that adequacy of ventilation was to be measured by the carbon dioxide content of the air and adequate ventilation required that 30 cubic feet of air per person per minute be pumped into a room. When the American Society of Heating and Ventilating Engineers was formed in 1895, it naturally put its support behind the accepted theory of ventilation and beginning with 1900 it wrote it into the statute books with a force quite unjustified by its scientific validity. That scientific validity was completely discredited by the New York State Commission in its report. This commission recommended a type of ventilation as follows:

1. A thermometer with a danger signal at 68° F.
2. Windows open at the bottom.

3. Deflecting boards at the bottom of the window.
4. Radiators extending the entire width of the windows equipped with hand control valves.
5. Exhaust ducts equipped with dampers located near the ceiling on the wall opposite the windows. Two ducts to the average school room.

With these things in mind the American Public Health Association in 1926 passed resolutions including the following statement:

"That the system of ventilating schoolrooms by fresh untreated outdoor air, admitted at the window with gravity exhaust ducts for removing vitiated air from near the ceiling is the most generally satisfactory method of school ventilation, and that state laws and city regulations interfering with such scientific and economical methods of school ventilation should be repealed in the interest of public health."

Method of Study. Two schools from Delaware County, Indiana, were chosen. Both schools receive their pupils chiefly from the surrounding farms. The Harrison Township school was located about four miles from Gaston while the Liberty Township school is at Selma.

The Harrison building is equipped with a hot water system of heating. The radiators are all situated along the outside wall of the rooms and under large windows. These windows are divided into numerous small panes and may be opened in small sections to admit air. There is no mechanical ventilating system. The outside wall is also pierced with ventilators which are $10\frac{1}{2}$ by $28\frac{1}{2}$ inches on the outside. The air enters these and comes into a duct at the bottom of a radiator and passes by the heated coils of the radiator and into the room. These ducts are so constructed that they may be closed completely, half open or entirely open. In the opposite wall at the floor is the opening of an exhaust duct which draws the vitiated air out of the room. This duct contains a radiator which heats the air, causing it to ascend and leave the building at the roof.

Each room is provided with a thermometer and each teacher is instructed to watch and regulate the temperature, by means of the ventilators, radiators and windows. Of course the circulation of air is entirely dependent upon the amount of fresh air admitted into the room. In this way the teacher is entirely responsible for the air which her students must breathe. The comfort and welfare of the pupils now becomes dependent upon the training of the teacher in physiology which will keep her alert and intelligently at her best.

The Selma school has the customary mechanical fan system. The air is continually blown into and drawn out of the rooms at a uniform rate through registers in the wall. The temperature is governed by a thermostat and the teacher has no special duty since she is not permitted to open the windows. However, in case the room becomes unbearable she may open the door into the corridor.

The criteria selected to judge the ventilation were temperature, humidity, air currents, absences occasioned by respiratory troubles, and the general comfort of the room.

The fifth grade rooms and a high school class room in each building

were selected to be studied. These rooms were visited from time to time during the months of November, December, January, February and March. At each visit the temperature, relative humidity, air currents and general comfort were noted.

The temperature and humidity were taken by means of a hygro-thermograph. The air currents were registered by means of flags tied to the registers and at Harrison School by means of flags at the outlets and the amount of the openings in the ventilators. The temperature registered by the thermometer in the rooms was in every case checked.

Results. It was found impossible to keep an accurate check upon the respiratory illnesses which occurred, since some of the teachers failed to keep records and the visits made to the schools were too infrequent, but the records indicated that when absences occurred they were in the majority of cases due to colds, sore throat or influenza.

The following chart gives the attendance percentage for each group. The average attendance at Harrison is higher than at Selma, but this does not necessarily prove that the percentage of respiratory illness is less, although it appears that such is the case.

	SELMA SCHOOL		HARRISON SCHOOL	
	Fifth Grade	High School	Fifth Grade	High School
Nov.	96.6%	92%	96.6%	95.9%
Dec.	94%	93%	94.8%	96.5%
Jan.	97.5%	95%	94.5%	96%
Feb.	93.5%	93%	96.6%	97.3%

Table I indicates the range of temperature, and humidity of each room as well as the air currents, condition of windows and ventilators and the general comfort.

From these figures it can be seen that the relative humidity of the Harrison building is higher than the Selma building, although neither is too dry for a school room. The temperature in the Selma building is more constant, which is not necessarily desirable, although in the Harrison building it has been allowed to range too high. In Selma there was always a good circulation of air due to the fan while many times at Harrison the circulation was stopped because a teacher failed to open the ventilators and windows.

Conclusion. From the results obtained no definite conclusion can be drawn as to the superiority of either system as it is working at present. Each system presents difficulties. The chief difficulty with the system at Harrison seems to be in the teachers. Each teacher has it in her power to control the air and temperature in her room, but the above data show that they are very lax in doing so. Perhaps in their busy class work they fail to realize how much the success and health of their students depend on the air that they breathe and the temperature of the room. If each teacher could be impressed with her responsibility, we believe that the Harrison system would prove most satisfactory because the air need not be over-heated as in a fan system, it circulates readily, and is sufficiently moist and clean to be called fresh air.

TABLE I. Atmospheric and other conditions recorded at the Selma and Harrison Schools.

SELMA FIFTH GRADE						HARRISON FIFTH GRADE							
Date	Temp.	Hum.	Current	General Comfort	Ventilators	Windows	Date	Temp.	Hum.	Currents	General Comfort	Ventilators	Windows
Nov. 20	72	60	Good	Comf.	.....	Closed	Nov. 20	74	78	Fair	Too Warm	Open	Closed
Nov. 30	71	69	Good	Comf.	.....	Closed	Nov. 30	72	60	Fair	Warm	Open	Open
Dec. 10	76	44	Fair	Stuffy	.....	Closed	Dec. 14	74	50	Good	Comf.	Open	Closed
Jan. 5	72	42	Good	Hot	.....	Door Open	Jan. 6	70	55	Good	Comf.	Open	Closed
Jan. 12	74	39	Good	Comf.	.....	Closed	Jan. 12	72	45	Poor	Stuffy	Half Open	Closed
Jan. 31	72	42	Poor	Too Warm	.....	Door Open	Feb. 9	72	57	Excellent	Comf.	Open	Open
Feb. 18	72	40	Good	Comf.	.....	Door Open	Feb. 18	74	48	Fair	Too Warm	Half Open	Door Open
Feb. 25	72	34	Good	Comf.	.....	Closed	Feb. 25	72	42	None	Stuffy	Closed	Closed
Mar. 2	72	35	Good	Comf.	.....	Closed	Mar. 2	72	42	Poor	Stuffy	Half Open	Closed
Mar. 9	72	32	Good	Comf.	.....	Closed	Mar. 9	76	51	None	Hot	Closed	Closed
SELMA HIGH SCHOOL						HARRISON HIGH SCHOOL							
Date	Temp.	Hum.	Current	General Comfort	Ventilators	Windows	Date	Temp.	Hum.	Currents	General Comfort	Ventilators	Windows
Nov. 20	72	50	Good	Comf.	.....	Closed	Nov. 20	70	77	Good	Comf.	Open	Closed
Nov. 30	74	74	Good	Stuffy	.....	Closed	Nov. 30	74	45	Poor	Hot	Closed	Closed
Dec. 10	70	55	Good	Comf.	.....	Closed	Dec. 14	72	49	Fair	Stuffy	Half Open	Closed
Jan. 5	74	43	Good	Hot	.....	Closed	Jan. 6	68	54	Good	Comf.	Open	Closed
Jan. 12	70	35	Good	Comf.	.....	Closed	Jan. 12	72	50	Fair	Comf.	Open	Closed
Jan. 31	74	43	Good	Too Warm	.....	Closed	Feb. 9	70	55	Fair	Fairly	Half Open	Closed
Feb. 18	74	40	Good	Too Warm	.....	Closed	Feb. 18	70	60	Good	Comf.	Open	Open
Feb. 25	71	37	Good	Too Warm	.....	Closed	Feb. 25	66	57	Good	Comf.	Open	Closed
Mar. 2	75	35	Good	Hot	.....	Closed	Mar. 2	72	42	Poor	Stuffy	Closed	Closed
Mar. 9	72	39	Good	Comf.	.....	Closed	Mar. 9	68	54	Poor	Hot	Closed	Closed

The Selma building is equipped with a fan system which functions as effectively as the average fan system. However, as may be expected, the temperature is too high and too constant for ideal conditions.

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NOTES ON THE TECHNIQUE OF PLANT MOUNTING.

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Some of our most beautifully flowered plants in ordinary mounting technique as dried specimens become devoid of shape, structure, and even appearance to serve for good identification. Flowers, of orchids particularly, not only dry poorly, but lose all semblance of appearance of the living plant. We have found it convenient to seal such parts in ordinary test tubes in an appropriate medium, and they may thus be kept indefinitely. This may be done rapidly by putting, for example, individual flowers of *Habenaria*, etc., in a test tube, and pouring in a mixture of equal parts absolute alcohol and xylol. This is changed several times until all or most all of the water is removed by the alcohol of the mixture, and may finally be replaced by pure xylol. Petals and sepals are then rendered quite transparent and inner parts of flower-buds may be seen and examined with an ordinary lens. In xylol, the plant parts are but slightly, if at all, contracted in size but it is usually advantageous to have some alcohol present in the mixture or the transparency will be so marked in small flowers that they may be rendered almost invisible. Such specimens may be kept for many years if hermetically sealed, which is, with a little practice, quite easily and expeditiously done. If the dehydration is done rapidly, which is quite feasible with small flowers, the alcohol often extracts the water so rapidly that the color of the petals is left, giving quite a lifelike appearance to the specimens.

The procedure is as follows: Several flowers are put into a test tube with a height of about four cc. of alcohol, xylol, or xylol mixture at the bottom. The top of the test tube is sealed to a glass rod or tube and pulled out into a thin capillary, by heating with a bunsen burner. The tube is bent back by momentary heating in a small flame. The lower end of the capillary is put into a beaker of xylol. As the tube cools, part of the liquid is sucked into the test tube. By heating the tube near the top of the level of liquid this is quickly brought to boiling using a small pilot flame on the burner, without noticeably heating the specimens at the bottom of the test tube. On removing the flame, more of the liquid runs in to replace the vacuum caused by the forced-out air. The test tube is cooled in a beaker of water and while cooling, is sealed off. If this sealing is done quickly while the cooling takes place, the tip will not blow out but can be heated to a hard, thick point. The tubes are then fastened to ordinary mounting sheets with the dried plants, and attached with adhesive tape.

Such test tubes and other parts of plants, some with natural colors preserved can be kept for years. We have a longitudinally sectioned flower of *Opuntia Rafinesquii* that has been preserved since 1915 when

we first began making such specimens. Parts of plants brought up so as to serve for histological material could be so brought up to xylol, and left sealed until used. They should, however, pass through the regular process for the paraffine sections. This method is longer, but for ordinary specimens for examination, fixing in chromaceatic acid and its accompaniments are not necessary. It is not advisable to treat material with the xylol mixture before transferring to the test tube as this fluid renders the plant parts rather brittle. The method of preservation could of course be made use of for zoölogical specimens.

RECENT INDIANA WEEDS, 1927.¹

ALBERT A. HANSEN, Purdue University Agricultural Experiment Station.

In this paper is recorded the occurrence in Indiana of plants known to possess weedy characteristics and which are new in the state or else have recently developed troublesome tendencies. It covers the period from October 1, 1926, to October 1, 1927, and is a continuation of previously published papers on the same subject.

For assistance in verifying identification, thanks are due the Division of Economic and Systematic Botany of the United States Department of Agriculture. Specimens of the plants listed have been deposited in the herbarium of the Purdue University Agricultural Experiment Station.

Cultivated Garlic (*Allium sativum* L.). In the vicinity of Madison a number of farms, gardens, and a cemetery are infested with the escaped form of the cultivated garlic, believed to be descendents of garlic that was formerly extensively cultivated in gardens. In common with its relative *A. vineale* L., the wild form of the cultivated garlic possesses bulbs that break into bulblets, varying in number from 6 to 20 or more, each of which is capable of forming a new plant the following season. Tests conducted in a cemetery near Madison indicate that the plant can be controlled by fall plowing in such a manner as to bury the tops and expose the bulbs to frost, the process requiring three years for complete success. The wild form of the cultivated garlic is a taller, ranker growing species than either *A. vineale* L. or *A. canadense* L., both commonly called wild garlic or wild onion, and possesses broader, flattened leaves.

Beefsteak Plant.—(*Perilla frutescens* (L.) Britton). On a number of farms in Indiana, particularly in Bartholomew County, the beefsteak plant is a serious weed, seeming to thrive equally well in open pastures and in wooded areas, where all forms of livestock seem to leave it untouched. It is an annual, a member of the mint family, growing to an average height of about three feet and is a native of India. Said to be an escape from garden cultivation, although on most farms where the species occurs in Indiana it seems to have been introduced through the medium of impure grain and clover seed.

Spanish Bayonet.—(*Yucca filamentosa* L.). Throughout the southern half of Indiana, notably in Monroe, Morgan and Daviess counties, the Spanish bayonet or Adam's needle escapes from cultivation, particularly in cemeteries, when allowed to go to seed and becomes an exceedingly difficult plant to eradicate. When cut before seeds ripen, the

¹ Contribution from the Department of Botany, Purdue University Agricultural Experiment Station.

plant stays well within its bounds. Seems to prefer sandy soil but will persist almost anywhere once the seedlings are allowed to form.

Blueweed.—(*Echium vulgare* L.). A common eastern species described by Coulter as "sparingly found in the northern part of the state," has developed into a very troublesome weed in the vicinity of Lagrange where it covers many acres on a number of farms, particularly on pasture land, and is difficult to combat. Specimens were collected in full flower on June 29, 1927.

Leafy Spurge.—(*Euphorbia esula* L.). A species equipped with deep-seated, heavy perennial rootstocks that seems to be capable of becoming a serious farm pest although not as yet troublesome in Indiana. In Orange County, New York, the leafy spurge is a major weed problem. Specimens in full flower were collected near Winamac, where it is established along roadsides, on June 20, 1927.

Purple-Head Sneezeweed.—(*Helenium nudiflorum*, Nutt.). Usually described as growing in moist places and said to be infrequent in Indiana, this species is a troublesome farm weed in Daviess County on dry, barren hillsides. It begins to bloom during late July and dies down during early October. No stock will touch it.

Meadow Barley (*Hordeum nodosum* L.). A species that can readily be confused with *H. pusillum* Nutt., found growing abundantly in Vanderburgh County during July and probably prevalent elsewhere in the state. A specimen was critically examined by C. C. Deam and pronounced genuine *H. nodosum*.

PLANTS NEW OR RARE IN INDIANA—XIV.

CHAS. C. DEAM, Bluffton.

Specimens of the plants reported in this paper are deposited in the Deam Herbarium with the exception noted. The determinations have in all cases been made or checked by specialists and I believe they are correct. The *Carex* were named by Kenneth K. Mackenzie; the *Acalypha* by C. A. Weatherby; the *Perularia*, *Phlox* and *Spiranthes* by E. T. Wherry, and the *Bidens* by Earl E. Sherff.

Equisetum Nelsoni (Eaton) Schaffner. Lake County, Sept. 20, 1927, No. 45,442. On an interdune flat just south of Pine. Steuben County, Sept. 20, 1914, No. 15,516. In a dry woods on the east side of Lake James. Whitley County, Sept. 11, 1916, No. 21,754. Low sandy border of the northeast shore of Crooked Lake, near the Noble County line. Determined by John N. Schaffner.

Lycopodium complanatum var. *flabelliforme* Fernald. Martin County, June 22, 1927, No. 44,688. On the slope of a stone cut along the abandoned right of way of the B. & O. Railroad about one mile south of Willow Valley. Determined by William R. Maxon.

Carex albicans Willd. Jasper County, June 6, 1924, No. 40,543. In a sandy black oak flat about two miles southwest of Tefft, Newton County, May 11, 1919, No. 27,392. Low place in a black oak woods about five miles northwest of Morocco. Porter County, June 4, 1924, No. 40,483. Along the east line of the Dunes State Park. Pulaski County, June 9, 1923, No. 38,839. Right of way of the Penn. Railroad two and a half miles southeast of Volz. Scott County, May 12, 1924, No. 40,137. Frequent in an open white oak woods one-half mile east of Lexington. Starke County, June 6, 1920, No. 30,890. Flat sandy black oak woods three miles southwest of Grovertown. Also in a sterile place in a black-pine oak woods five miles northwest of Knox.

Carex austrina (Small) Mackenzie. Benton County, June 19, 1926, No. 43,219. On an open sandy burr oak ridge seven miles east of Fowler.

Carex Bushii Mackenzie. Posey County, May 25, 1925, No. 42,929. Common in an open post oak woods on the south side of Half Moon Pond about eight miles southwest of Mt. Vernon. Spencer County, May 28, 1926, No. 43,023. In an open pin-post oak flat about two miles southeast of Dale.

Carex Hassei Bailey. Lake County, June 21, 1926, No. 43,294. On an interdune flat about one-fourth mile south of Pine. Newton County, June 3, 1927, No. 44,413. Bottom of old Beaver Lake about five miles southwest of Conrad.

Carex heliophila Mackenzie. Jasper County, June 6, 1924, No. 40,538. In a sandy black oak woods about two miles southwest of Tefft.

Carex Meadii Dewey. Benton County, June 3, 1927, No. 44,436. Rare in low ground along the right of way of the Big Four Railroad about one and one-fourth miles northwest of Earl Park. Intimately associated with *C. lanuginosa*. This species was reported for "Sheffield, south to Pine Station; rare" (Lake County) by Higley and Raddin.¹

Carex nigro-marginata Schwein. Crawford County, April 24, 1927, No. 44,074A. Associated with *C. umbellata* Schk. on the top of the wooded bluff of the Ohio River about one-fourth mile north of Fredonia.

Carex ormostachya Wiegand. Porter County, May 31, 1927, No. 44,381. Dry place in a beech-sugar maple woods about three and one-half miles northeast of Valparaiso.

Carex rugosperma Mackenzie. Lake County, June 5, 1924, No. 40,514. In a sandy black-white oak woods about one mile southwest of Griffith.

Carex strictior Dewey. I have this species from Allen, Jasper, Lagrange, Lake, Marshall, Noble, Porter, Starke, Sullivan, Tipton and Wells counties.

Carex tribuloides var. *sangamonensis* Clokey. Boone County, June 26, 1926, No. 44,829. About a pond in a woods about one and one-half miles southwest of Advance.

Perularia scutellata (Nutt.) Small. Posey County, Sept. 28, 1923, No. 39,915. A thrifty colony growing in a bare place in under a clump of buttonbush in a low woods about ten miles southwest of Mt. Vernon. This low pocket in this swamp must be under water much of the year, since no vegetation was found in it except this orchid which seemed to be at home in it. When collected it was named for me by a specialist as *P. flava*. I transferred some of it to our garden where it has thrived ever since. In September, 1927, E. T. Wherry, who visited our garden, at once recognized this plant as the one reported.

Spiranthes ovalis Lindley. Crawford County, Oct. 5, 1920, No. 33,409. Wooded bluff of the Ohio River on the north side of Leavenworth. Spencer County, Oct. 3, 1923, No. 39,962. In rather sandy soil on a wooded slope in Section 3, about three-fourths mile southeast of Enterprise. This species was detected in my herbarium by E. T. Wherry under the name of *S. cernua* which it closely resembles.

Eleocharis rostellata Torrey. I have this species from Henry, Lagrange, Marshall and Noble counties. This species has been reported for southwestern Indiana but no definite locality is given. The habitat of this plant is given "as salt marshes and alkaline soil." In the four stations I found it, it was growing in very marly soil, which makes the southwestern record somewhat dubious.

Aconitum uncinatum L. C. W. Short in "A Fourth Supplementary Catalogue of the Plants of Kentucky," published in September, 1840,

¹ Bull. Chicago Acad. Sci. 2:134, 1891.

says he found it "in the barrens of Harrison County." In the Philadelphia Academy of Sciences which has Doctor Short's herbarium, I found two plants collected by Short. One was dated Sept., 1840, and collected "in the barrens of Ia. near Corydon." The other dated Oct., 1842, was collected "in the barrens of Indiana near Corydon."

Acalypha digyneia Raf. In Indiana this species has been going under the name of *A. gracilens* but it is quite distinct from that species. I have it from the following counties: Clark, Crawford, Dubois, Floyd, Fountain, Franklin, Gibson, Greene, Harrison, Jackson, Jennings, Martin, Monroe, Orange, Owen, Perry, Posey, Spencer and Washington.

Acalypha virginica var. *Deamii* Weatherby. I have this variety from Dearborn, Gibson and Spencer counties. The range of this variety is given as southern Indiana, but I am certain I have seen specimens of it in the National Herbarium and in the herbarium of the Missouri Botanical Garden.

Osmorrhiza longistylis var. *brachycoma* Blake. Marion County, May 25, 1912, No. 10,643. In the "buzzards' roost" woods about 12 miles northeast of Indianapolis.

Phlox amplifolia Britton. I have this species from Crawford, Harrison and Perry counties.

Scutellaria saxatilis Riddell. Crawford County, June 9, 1919, No. 27,829. In talus at the base of a cliff along Little Blue River where the Carnes mill was located, about three miles south of Grantsburg. This place was revisited on June 19, 1927, and additional specimens collected. The colony is about the same size as when first discovered. I was not able to find this species elsewhere.

Diapedium brachiatum (Pursh) Kuntze. Warrick County, Oct. 2, 1927, No. 45,614. Abundant at and near the base of a wooded slope on the Nathan Taylor farm about one-half mile west of Yankeetown.

Bidens aristosa var. *Fritcheyi* Fernald. Ripley County, Sept. 23, 1922, No. 38,126. Roadside ditch three miles southwest of New Marion. Sullivan County, Aug. 24, 1912, No. 12,160. Roadside four miles west of Shelburn.

Bidens aristosa var. *mutica* (Gray) Gatt. Porter County, Sept. 15, 1918, No. 26,524. Along the Kankakee River near the Baum Bridge; also found later three miles northeast of Kouts. Vermillion County, Sept. 29, 1912, No. 12,482. In a prairie habitat in wet soil along the roadside about one and one-half miles east of Dana; and later along the roadside one mile south of Toronto.

Bidens involucrata var. *retrorsa* Sherff. Owen County, Sept. 22, 1921, No. 35,010. Roadside one-half mile north of Coal City, and frequent in an adjoining field.

MONSTROSITIES IN TRILLIUM.

F. M. ANDREWS, Indiana University.

From 1905 to 1926 the writer has discussed in the Proceedings of the Indiana Academy of Science certain deviations in plants from the normal. In 1905 the discussion was relegated entirely to the genus *Trillium*. A further contribution by the writer appeared in 1906 where three species of *Trillium* are described and illustrated as to monstrosities. The literature is also given in the above cited papers.

The author has found by a study and observations extending over many years that of the genus *Trillium*, the so-called "snow trillium," or *Trillium nivale* tends less to depart from its usual characters than any other of the several species he has investigated. In a continuous study of *T. nivale* over more than 20 years a slight tendency was noted (p. 83) "in only a few instances toward a monstrosity." "This occurred in the transplanted specimens and was evidenced by a partial transformation of the petals in one of the flowers to leaves." This instance of phyllody in *T. nivale*, however, seems to be extremely rare and is all the more surprising when it is remembered that the genus *Trillium* is rather inclined to monstrosities in instances of phyllody in various of the species. Only a slight union of floral parts has been observed by the writer in *T. nivale* growing in the wild state.

Anthesis in most flowers was greatly delayed in the year 1924 due to the seasonal conditions. A difference of 21 days was shown in this respect by many plants due in large measure to low temperature. The *Trilliums* while not so late in blooming as some other plants, were nevertheless considerably retarded. A comparison of the date of blooming of plants, such as *Trillium* in 1924, with the record kept by the writer of former years when conditions were more normal, showed a striking difference. The *Trillium* flowers in the region of Marengo and Wyandotte caves were open eight days before those about Bloomington, although the distance is only about 65 miles. Unusual variations were observed in the Marengo region in *Trillium*. Several specimens of *T. recurvatum* as well as *T. sessile* and *T. erectum*, possessed flowers, which as regards the number of parts, were in some cases supernumerary and in other cases were subnumerary. An unusual number of the flowers of *T. erectum* possessed brilliantly pink petals and far in excess as regards intensity of color of that generally observed. The petals were twice the natural size.

T. sessile is especially inclined to deviations of the above mentioned variety. Deviations in the genus *Trillium* have been noted by many writers and the literature on this topic has been referred to in some detail in the writer's previous papers. Holzinger has mentioned and illustrated a monstrosity in *T. grandiflorum* similar to that observed by

the writer in *T. sessile*, but with a smaller number of parts. *T. sessile* when showing a monstrosity as above indicated, so far as observed, is always smaller than other individuals of that species in the same locality which are normal in other respects. The parts of the flower in *Trillium*, as above indicated, are not always increased but are sometimes decreased in number as the writer has further described in the case of *T. erectum*. The writer found another specimen of *T. sessile* which was transplanted in the spring of 1926, in order to follow out some of the above points. This has, heretofore, not been so easily attended with success as might seem to be easily possible. This is all the more unusual in as much as it is well known that plants of the genus *Trillium* are easily transplanted and successfully grown where ordinary care is exercised, as the writer has shown by an experiment extending over a long period of years. The specimen of *T. sessile* above mentioned which the writer has under observation had in 1926 the usual number of parts in only the androecial whorls. This flower had four sepals, four petals, the usual six stamens and four styles. All these parts showed in part the usual relation with reference to one another but all were much smaller than the normal specimens, for the various flower parts measured only one-third the size of similar parts in the control plants which were used for comparison. There were also four foliage leaves on this specimen of *T. sessile* in 1926 instead of the usual three leaves. These also, like the flower, were much smaller than those of the normal plants in the same vicinity. Their length was only one-third and their breadth one-half that of the average dimensions of the normal plants. This year (1927) this specimen of *T. sessile* did not revert to the usual number of parts. There were present three leaves, four sepals, three petals, four stamens and four styles. All the various parts were still below the normal size.

MODIFIED NARCISSUS FLOWERS.

F. M. ANDREWS, Indiana University.

The writer has observed some specimens of *Narcissus Pseudo-Narcissus* whose flowers showed an unusual form and color. As stated by Bailey the flowers are "seldom green." In the so-called "full-flowers" part of the flower divisions of my specimens were more or less green and others entirely so, as stated below. This was particularly noticeable in the case of those plants which had been in cultivation for a protracted period. Within the last ten years during which time the plants have been under observation, from year to year, the green color gradually advanced in the segments of the "full-flowers" that were produced each season, until finally in the tenth year all of the flowers of the specimens, here referred to, were entirely green. The change from light yellow to green nearly always began in the peripheral division of the flower and proceeded inward toward the center. As regards the individual segments of the "full-flowers" the change to a green color

began at the tip and progressed downward, and in the first years of observation this advance was very evident during the period of blooming. However, in certain "full-flowers" some of the segments near the center of the flower showed an advanced stage of chlorophyll formation even before its completion in the outer divisions. In these flowers the trumpet was entirely absent.

A few other specimens possessed flowers of an unusual form. One of these bore a general resemblance to *Narcissus incomparabilis*. The leaves were slightly more pointed but the chief points of difference were in the flowers. The flowers were nearly erect and large with rather pointed segments. One of the chief differences was noticeable in the corona. This equaled the segments in length and was broadly barrel-shaped. The outer end of the corona instead of flaring out, was strongly constricted and showed a fringe-like border of very narrow divisions. The color of the corona was deep yellow except the fringe-like border which was of a very light yellow color. The stamens and style were included as in the common *N. incomparabilis*. Only a few flowers showed the above mentioned differences and were growing among a large number of other specimens all of which were *N. incomparabilis*. For this reason the deviations above mentioned were all the more noticeable, and therefore stood out with surprising distinctness in comparison to the hundreds of uniformly shaped flowers of *N. incomparabilis* which immediately surrounded them. A dense bed of *N. poeticus* in which an actual count showed more than 4,000 flowers, which were fully open at the same time, showed only a slight tendency in two of the flowers to deviate from the normal. These two specimens suggested slightly the form assumed by *N. poeticus* var. *plenus*. Of all the forms of *Narcissus* which I have grown and kept under observation during the last ten year, *N. poeticus* has retained the original type form most perfectly.

DEPOSITION OF MATERIAL BY WATER PLANTS.

F. M. ANDREWS, Indiana University.

It is a matter of common knowledge that various organisms, such as plants, play an important rôle in the deposition of material in bodies of rather still water, as for example, lakes and ponds. This takes place to a very noticeable degree in many ponds having a heavy growth of vegetation in the water, and into which very little soil is carried by erosion. When, however, plant activity, as here referred to, is supplemented by erosive action of the surrounding land, complete obliteration of considerable bodies of water, such as shallow ponds, may occur in a comparatively short time. This has been observed by the writer to progress rather rapidly in the case of some shallow ponds. About some ponds and lakes erosion is not an inimportant factor in this respect as was found by Evermann and Clark for Lake Maxinkuckee. Birge and Juday have estimated the organic matter in Lake Monona. Some deposition,

however, of soil and other materials in lakes and ponds inevitably takes place. The exact amount of material, therefore, deposited by plants is in such cases an uncertain quantity. However, the writer has been studying the problem for some years by means of experiments where water plants only were involved. The experiment was performed as follows: Jars having a capacity of about four liters were filled to a depth of three cm. with cleanly washed sand on top of which was placed washed gravel. Other jars of equal capacity were used in which no sand or gravel was placed. All six of the jars so arranged, which included three of each kind, were filled with tap water. Five sprays of *Elodea* each ten cm. long were placed in each jar, and an equal number of *Chara* plants. The loss of evaporation was replaced by occasional additions of tap water. The *Elodea* grew rapidly at first and finally practically filled the jars. By the end of six months the *Elodea* was, for the most part, displaced by the *Chara* plants and various algae which had appeared, especially *Gloeocapsa*. When the experiment was one year old every vestige of *Elodea* had been crowded out and the *Chara* was reduced about one-half of its former amount, as it, like the *Elodea*, was unable to withstand the competition with the rapidly increasing *Gloeocapsa*. Meanwhile, heavy deposition of material from the dead plants had taken place and had assumed a depth of one-half cm. by the end of the first year over the bottom of the jars. Since the sand and gravel layers, above mentioned, interfered with a quantitative estimation of the amount of deposited material, those jars containing such substances were discontinued after the first year. Only those jars having no floor of sand and gravel were observed after the first year till the completion of these observations. By the end of the second year not more than one-fourth of the *Chara* was growing in the jars, but other forms, especially *Gloeocapsa*, had greatly increased. The deposition of material averaged 12 mm. in depth on the bottom of the jars by the end of the second year. The first year's deposit had meanwhile become denser. During the third year the deposited material increased to a depth of four cm. and with a further increase in density of the first two year's deposition. During the third year a further decline in activity and amount of the *Chara* was noticeable and a decided increase in the algae forms was evident. The fourth year marked an increase of two and one-half cm. of deposited material but still a considerable growth of *Chara* was present. The fifth year showed only a small amount of *Chara* present, but a large increase of algae forms and a loose deposition of three cm. of material. The algae, dense as it was, could not displace the *Chara* and this has been an observation in large pools and tanks out of doors.

Hence many of the larger forms of water plants may be readily crowded out or reduced to a minimum by various algae growths. The algae may be easily destroyed by the method of Moore and Kellerman. During the second and third years a very dense growth of *Polyridium cruentum* occurred but this alga was not present in any other year's growth. The various forms of algae and deposited material varied considerably in thickness in different parts of the jar. While these depositions at first were very loosely deposited and were unusually

thick, as above stated, in the year formed, the layers of each year became finally very compact and were only a fraction of the original thickness. Of all the forms of plants present, *Gloeocapsa* was by far the most numerous and was of greatest volume. The algae found during the several years above referred to in the jars, numbered 32 species. Not all were, by any means, present at one time; but they came and went according to the general conditions of growth. Quite a number could be found at any one time. Of the forms observed, *Pediastrum* was the least numerous and was found only during the first weeks of the observation. The resistance of *Chara* to a dense growth of other forms was well shown in this experiment. As was the case with *Elodea* nearly every other species of higher forms would have been crowded out under the conditions here described and in a comparatively short time.

A STUDY OF LICHENS.

F. M. ANDREWS, Indiana University.

It is frequently of interest to ascertain why plants are living in certain places and how they maintain their existence in definite areas. On the other hand it is equally valuable to ascertain, when they disappear wholly or partly, what forms vanish first, what ones partly and what ones remain. It has long been known that one striking fact concerning lichens is the apparent ease with which they are crowded out by civilization. At the end of the following list of lichens of Monroe County, these points will be briefly indicated.

Peltigera canina, *P. rufescens*, *P. horizontalis*, *Lecidea melancheima*, *Gyrophora mühlenbergii*, *Graphis scripta*, *Collema pulposum*, *Leptogium scotinum*, *Teloschistes polycarpus*, *T. lychnus*, *T. concolor*, *Umbilicaria pustulata*, *Amphiloma lanuginosum*, *Thamnomia vermicularis*, *Acarospora chlorophana*, *Trypethelium virens*, *Verrucaria rupestris*, *Pertusaria communis*, *P. vellata*, *P. Leioplaca*, *Endocarpon minutum*, *Leptogium tremelloides*, *Hydrothyria venosa*, *Nephroma helvetica*, *Lopadium periroideum*, *Pannaria leucosticta*, *P. lurida*, *Coniocybe pallida*, *Psora Russellii*, *Xylographa parallela*, *Arthonia radiata*, *Arthothelium spectabile*, *Rinodina sophodes*, *Placodium elegans*, *P. cinnabarrinum*, *Urceolaria scruposa*, *Lecanora Hageni*, *L. muralis*, *L. subfusca*, *L. pallida*, *Cladonia rangiferina*, *C. cristatella*, *C. pyxidata*, *C. verticillata*, *C. fimbriata*, *C. sylvatica*, *C. bacillaris*, *Usnea barbata*, *Physcia stellaris*, *P. speciosa*, *P. pulverulenta*, *P. tribacia*, *Parmelia perlata*, *P. rudecta*, *P. perforata*, *P. physodes*, *P. caperata*, *P. borrieri*, *Sticta amplissima*.

A few specimens of *Collema* were partly displaced by *Mucor* in very damp situations and this sometimes occurs when this form is kept very moist for some time in the laboratory. As is known dust is very destructive; hence many forms have vanished along dusty roads and streets. The great power of some forms to resist desiccation has been

overcome in certain types, therefore Collema and some others have disappeared from this cause alone. Smoke, especially in and about towns, has been very detrimental to these forms, as well as some other plants. Of the list given here, some genera will be mentioned in the order of disappearance. They have partly or wholly vanished during my observations of more than 20 years on these points, where the conditions have been much changed. The first genera to disappear were Collema, Peltigera, Sticta, Usnea, and Umbilicaria. The following forms have retained more or less completely their habitats. The first two are less common: Graphis, Lecidea, Physcia, Parmelia, and Cladonia. In the densely populated places all of these last five have entirely disappeared from limited areas.

SOME FLOWERING PLANTS OF MONROE COUNTY, INDIANA.

F. M. ANDREWS, Indiana University.

The following list of plants is a partial enumeration of the flowering plants of Monroe County which the writer has recorded over a stretch of many years and includes certain escaped and introduced forms. The families of plants mentioned in this list have been arranged in the same order as those of the seventh edition of Gray's Manual of Botany.

- TYPHACEAE: *Typha latifolia*
 NAJADACEAE: *Potamogeton natans*
 ALISMACEAE: *Sagittaria latifolia*, *Alisma Plantago-aquatica*
 HYDROCHARITACEAE: *Elodea canadensis*
 ARACEAE: *Arisaema triphyllum*, *Dracontium*, *Acorus Calamus*
 LEMNACEAE: *Lemna trisulca*
 COMMELINACEAE: *Tradescantia brevicaulis*, *pilosa*, *virginiana*, *Commelina virginica*
 PONTEDERIACEAE: *Heteranthera reniformis*
 JUNCACEAE: *Juncus tenuis*, *effusus*, *acuminatus*, *Luzula campestris*
 LILIACEAE: *Uvularia perfoliata*, *grandiflora*, *Allium tricoccum*, *cernuum*, *virgale*, *Hamerocallis fulva*, *Lilium canadense*, *Erythronium americanum*, *album*, *Camassia esculenta*, *Ornithogalum umbellatum*, *Muscari botryoides*, *Yucca filamentosa*, *Asparagus officinalis*, *Smilacina racemosa*, *Polygonatum biflorum*, *commutatum*, *Convallaria majalis*, *Medeola virginiana*, *Trillium sessile*, *recurvatum*, *erectum*, *nivale*, *Smilax herbacea*, *rotundifolia*, *Bona-nox*, *hispida*, *pseudo-china*
 DIOSCOREACEAE: *Dioscorea villosa*
 AMARYLLIDACEAE: *Narcissus pseudonarcissus*, *poeticus*, *Hypoxis hirsuta*
 IRIDACEAE: *Iris versicolor*, *I. cristata*, *Belamcanda chinensis*, *Sisyrinchium angustifolium*, *S. gramineum*
 ORCHIDACEAE: *Cypripedium parviflorum*, *acaule*, *Orchis spectabilis*, *Habenaria peramoena*, *Pogonia verticillata*, *Spiranthes gracilis*, *cernua*, *Epipactis pubescens*, *Corallorhiza odontorhiza*, *Microstylis unifolia*, *Liparis liliifolia*, *Aplectrum hyemale*
 SALICACEAE: *Salix nigra*, *amygdaloides*, *cordata*, *discolor*, *humilis*, *Populus alba*, *tremuloides*, *grandidentata*, *bal-samifera*, *deltoides*

- JUGLANDACEAE: *Juglans cinerea*, *nigra*, *Carya ovata*, *laciniosa*, *alba*, *microcarpa*, *glabra*, *cordiformis*
- BETULACEAE: *Corylus americana*, *Ostrya virginiana*, *Carpinus caroliniana*
- FAGACEAE: *Fagus grandifolia*, *Castanea dentata*, *pumila*, *Quercus alba*, *stellata*, *macrocarpa*, *bicolor*, *Prinus rubra*, *coccinea*, *texana*, *ellipsoidalis*, *velutina*, *nigra*, *palustris*, *imbricaria*
- URTICACEAE: *Ulmus fulva*, *americana*, *Celtis occidentalis*, *Cannabis sativa*, *Humulus Lupulus*, *Maclura pomifera*, *Morus rubra*, *alba*, *Urtica gracilis*, *Laportea canadensis*, *Pilea pumila*, *Boehmeria cylindrica*, *Parictaria pennsylvanica*
- SANTALACEAE: *Comandra umbellata*
- ARISTOLOCHACEAE: *Asarum canadense*, *Aristolochia Serpentina*
- POLYGONACEAE: *Rumex crispus*, *elongatus*, *obtusifolius*, *hastatulus*, *acetosella*, *Polygonum aviculare*, *lapathifolium*, *pennsylvanicum*, *Hydropiper acre*, *orientale*, *Persicaria*, *hydropiperoides*, *virginianum*, *sagittatum*, *scandens*, *dumetorum*, *Fagopyrum esculentum*
- CHENOPODIACEAE: *Chenopodium ambrosioides*, *Bonus-Henricus*, *glaucum*, *hybridum*, *Vulvaria*, *album*, *urbicum*
- AMARANTHACEAE: *Amaranthus retroflexus*, *hybridus*, *gracizans*, *spinosus*, *Gomphrena globosa*
- PHYTOLACCACEAE: *Phytolacca decandra*
- NYCTAGINACEAE: *Oxybaphus nyctagineus*
- ILLECEBRACEAE: *Anychia polygonoides*, *canadensis*, *Mollugo verticillata*
- CARYOPHYLLACEAE: *Arenaria serpyllifolia*, *stricta*, *Stellaria longifolia*, *pubera*, *media*, *Cerastium arvense*, *vulgatum*, *viscosum*, *nutans*, *Agrostemma Githago*, *Silene antirrhina*, *noctiflora*, *virginica*, *stellata*, *latifolia*, *Saponaria officinalis*
- PORTULACACEAE: *Claytonia virginica*, *Portulaca oleracea*, *grandiflora*
- NYMPHAEACEAE: *Nymphaea advena*, *Castalia odorata*
- RANUNCULACEAE: *Ranunculus abortivus*, *recurvatus*, *fascicularis*, *septentrionalis*, *repens*, *Thalictrum dioicum*, *Anemonella thalictroides*, *Hepatica triloba*, *acutiloba*, *Anemone virginiana*, *quinquefolia*, *Clematis virginiana*, *Isopyrum biternatum*, *Helleborus viridis*, *Aquilegia canadensis*, *Delphinium tricornis*, *Actaea alba*, *Hydrastis canadensis*
- MAGNOLIACEAE: *Liriodendron Tulipifera*
- ANONACEAE: *Asimina triloba*
- MENISPERMACEAE: *Menispermum canadense*
- BERBERIDACEAE: *Podophyllum peltatum*, *Jeffersonia diphylla*, *Caulophyllum thalictroides*, *Berberis vulgaris*
- LAURACEAE: *Sassafras variifolium*, *Benzoin aestivale*
- PAPAVERACEAE: *Sanguinaria canadensis*, *Stylophorum diphyllum*
- FUMARIACEAE: *Dicentra Cucullaria*, *canadensis*
- CRUCIFERAE: *Draba verna*, *Alyssum alyssoides*, *Lesquerella globosa*, *Thlaspi arvense*, *Lepidium virginicum*, *Capsella Bursa-pastoris*, *Brassica alba*, *arvensis*, *nigra*, *Sisymbrium officinale*, *Erysimum repandum*, *Radiola Nasturtium-aquaticum*, *sylvestris palustris*, *Armoracia*, *Barbarea vulgaris*, *Iodanthus pinnatifidus*, *Dentaria diphylla*, *heterophylla*, *laciniata*, *Cardamine bulbosa*, *Douglasii*, *hirsuta*, *pennsylvanica*, *Arabis dentata*, *hirsuta*, *laevigata*
- CAPPARIDACEAE: *Polanisia graveolens*, *trachysperma*
- CRASSULACEAE: *Penthorum sedoides*, *Sedum ternatum*
- SAXIFRAGACEAE: *Heuchera americana*, *Mitella diphylla*, *Hydrangea arborescens*, *Ribes Cynosbati*
- HAMAMELIDACEAE: *Hamamelis virginiana*, *Liquidambar Styraciflua*
- PLATANACEAE: *Platanus occidentalis*
- ROSACEAE: *Physocarpus opulifolius*, *Spiraea salicifolia*, *Aruncus sylvestris*, *Pyrus coronaria*, *Malus americana*,

- Amelanchier canadensis*, *Crataegus Oxyacantha*, *Crus-galli*, *punctata*, *coccinea*, *flava*, *tomentosa*, *Fragaria virginiana*, *vesca*, *Potentilla arguta*, *monspeliensis*, *norvegica*, *fruticosa*, *canadensis*, *Geum canadense*, *vernum*, *Rubus occidentalis*, *allegheniensis*, *canadensis*, *hispidus*, *villosus*, *Agri-monia striata*, *mollis*, *parviflora*, *rostellata*, *Rosa setigera*, *rubiginosa*, *carolina*, *virginiana*, *humilis*, *Prunus serotina*, *virginiana*, *angustifolia*, *Mahaleb*, *americana*, *Persica*
- LEGUMINOSAE: *Gymnocladus dioica*, *Gleditsia triacanthos*, *Cassia marilandica*, *Medsgeri*, *Cercis canadensis*, *Cladrastis lutea*, *Trifolium arvense*, *incarnatum*, *pratense*, *repens*, *hybridum*, *procumbens*, *Melilotus officinalis*, *alba*, *Medicago sativa*, *lupulina*, *hispida*, *Robinia Pseudo-Acacia*, *Desmodium nudiflorum*, *grandiflorum*, *rotundifolium*, *viridiflorum*, *Dillenii*, *paniculatum*, *Lespedeza procumbens*, *repens*, *violacea*, *hirta*, *Vicia Cracca*, *Phaseolus deversifolia*, *Strophostyles helvola*, *Amphicarpa monoica*
- LINACEAE: *Linum usitatissimum*, *virginianum*
- OXALIDACEAE: *Oralis violacea*, *stricta*, *corniculata*, *repens*
- GERANIACEAE: *Geranium maculatum*, *carolinianum*
- RUTACEAE: *Zanthoxylum americanum*
- SIMARUBACEAE: *Ailanthus glandulosa*
- EUPHORBIACEAE: *Acalypha virginica*, *Euphorbia serpyllifolia*, *Prellii*, *maculata*, *humistrata*, *marginata*, *corollata*, *Cyparissias*, *commutata*
- CALLITRICHACEAE: *Callitriche heterophylla*
- LIMNANTHACEAE: *Floerkea proserpin-acoides*
- ANACARDIACEAE: *Rhus glabra*, *copallina*, *Toxicodendron*, *canadensis*
- AQUIFOLIACEAE: *Ilex verticillata*
- CELASTRACEAE: *Evonymus atropurpureus*, *obovatus*, *Celastrus scandens*
- STAPHYLEACEAE: *Staphylea trifolia*
- ACERACEAE: *Acer saccharum*, *saccharinum*, *rubrum*, *Negundo*
- SAPINDACEAE: *Aesculus Hippocastanum*, *glabra*
- BALSAMINACEAE: *Impatiens pallida*, *biflora*
- RHAMNACEAE: *Rhamnus cathartica*
- VITACEAE: *Psedera quinquefolia*, *Cissus Ampelopsis*, *Vitis aestivalis*, *cordifolia*
- TILIACEAE: *Tilia americana*
- MALVACEAE: *Abutilon Theophrasti*, *Sida spinosa*, *Malva rotundifolia*, *sylvestris*, *Napaea dioica*, *Hibiscus Trionum*
- HYPERICACEAE: *Hypericum Ascyron*, *graveolens*, *punctatum*, *prolificum*, *mutilum*, *canadense*, *perforatum*
- VIOLACEAE: *Hybanthus concolor*, *Viola pedata*, *cucullata*, *sororia*, *papilionacea*, *sagittata*, *blanda*, *pubescens*, *scabriuscula*, *striata*, *Rafinesquii*
- PASSIFLORACEAE: *Passiflora lutea*
- LOASACEAE: *Opuntia vulgaris*
- THYMELAEACEAE: *Dicra palustris*
- LYTHRACEAE: *Lythrum alatum*, *Cuphea petiolata*
- ONAGRACEAE: *Ludvigia alternifolia*, *palustris*, *Epilobium coloratum*, *Oenothera biennis*, *fruticosa*, *Gaura biennis*, *Circaea lutetiana*, *alpina*
- ARALIACEAE: *Aralia racemosa*, *Panax quinquefolium*
- UMBELLIFERAE: *Sanicula canadensis*, *trifoliata*, *Erigenia bulbosa*, *Osmorhiza Claytoni*, *longistylis*, *Cicuta maculata*, *Cryptotaenia canadensis*, *Thaspium aureum*, *barbinode*, *Pastinaca sativa*, *Daucus Carota*
- CORNACEAE: *Cornus florida*, *alternifolia*, *Nyssa sylvatica*
- ERICACEAE: *Chimaphila maculata*, *Monotropa uniflora*, *Hypopitys*, *Epigaea repens*, *Gaylussacia frondosa*, *baccata*, *resinosa*, *Vaccinium stamineum*, *vaccillans*
- PRIMULACEAE: *Samolus Valerandi*, *Lysimachia Nummularia*, *thyrsiflora*, *Steironema ciliatum*, *lanccolatum*, *Anagallis arvensis*
- SAPOTACEAE: *Diospyros virginiana*

- OLEACEAE: *Fraxinus americana*, *Pennsylvanica*, *quadrangulata*, *Ligustrum vulgare*
- GENTIANACEAE: *Sabatia angularis*, *Gentiana Andrewsii*, *Obolaria virginica*
- APOCYNACEAE: *Vinca minor*, *Apocynum androsaemifolium*, *cannabinum*
- ASCLEPIADACEAE: *Asclepius tuberosa*, *incarnata*, *speciosa*, *syriaca*, *quadrifolia*, *Acerates floridana*, *Gonolobus laevis*
- CONVOLVULACEAE: *Ipomoea hederacea*, *purpurea*, *pandurata*, *lacunosa*, *Convolvulus sepium*, *arvensis*, *Cuscuta Gronovii*
- POLEMONIACEAE: *Phlox maculata*, *divaricata*, *bifida*, *Polemonium reptans*
- HYDROPHYLLACEAE: *Hydrophyllum macrophyllum*, *virginianum*, *appendiculatum*, *Phacelia bipinnatifida*, *Purshii*, *dubia*
- BORAGINACEAE: *Cynoglossum officinale*, *virginianum*, *Lappula virginiana*, *Symphytum officinale*, *Lycopsis arvensis*, *Mertensia virginica*, *Lithospermum arvense*, *latifolium*, *Gmelini*, *canescens*, *Echium vulgare*
- VERBENACEAE: *Verbena urticaefolia*, *angustifolia*, *hastata*, *stricta*, *bracteosa*, *canadensis*
- LABIATAE: *Teucrium canadense*, *Isanthus brachiatus*, *Scutellaria lateriflora*, *versicolor*, *canescens*, *Marrubium vulgare*, *Agastache nepetoides*, *Mechania cordata*, *Nepeta Cataria*, *hederacea*, *Prunella vulgaris*, *Synandra hispidula*, *Lamium amplexicaule*, *album*, *Leonurus Cardiaca*, *Stachys tenuifolia*, *Monarda clinopodia*, *fistulosa*, *Blephilia ciliata*, *hirsuta*, *Hedeoma pulegiodes*, *Pycnanthemum flexuosum*, *incanum*, *muticum*, *Cunila origanoides*, *Lycopus virginicus*, *americanus*, *Mentha spicata*, *piperita*, *Collinsonia canadensis*
- SOLANACEAE: *Solanum Dulcamara*, *nigrum*, *carolinense*, *rostratum*, *Physalis pubescens*, *viscosa*, *subglabrata*, *Nicandra Physalodes*, *Lycium halimifolium*, *Datura Stramonium*, *Tatula*
- SCROPHULARIACEAE: *Verbascum Thapsus*, *Blattaria*, *Linaria vulgaris*, *Scrophularia marilandica*, *Pentstemon hirsutus*, *laevigatus*, *Chelone glabra*, *Mimulus ringens*, *alatus*, *Conoclea multifida*, *Ilysanthes anagallidea*, *Gratiola virginiana*, *Veronica officinalis*, *serpyllifolia*, *peregrina*, *arvensis*, *Seymeria macrophylla*, *Gerardia flava*, *virginica*, *tenuifolia*, *Pedicularis canadensis*
- OROBANCHACEAE: *Epifagus virginiana*, *Conopholis americana*, *Orobanche uniflora*
- BIGNONIACEAE: *Tecoma radicans*, *Catalpa speciosa*, *bignonioides*
- ACANTHACEAE: *Dianthera americana*, *Ruellia strepens*
- PHRYMACEAE: *Phryma Leptostachya*
- PLANTAGINACEAE: *Plantago major*, *Rugelii*, *lanceolata*, *aristata*, *virginica*
- RUBIACEAE: *Galium Aparine*, *circaeans*, *latifolium*, *trifidum*, *tinctorium*, *concinnum*, *triflorum*, *Mitchella repens*, *Cephalanthus occidentalis*, *Houstonia caerulea*, *purpurea*, *longifolia*
- CAPRIFOLIACEAE: *Lonicera sempervirens*, *dioica*, *Symphoricarpos orbiculatus*, *Triosteum perfoliatum*, *angustifolium*, *Viburnum acerifolium*, *Lentago*, *prunifolium*, *Sambucus canadensis*
- VALERIANACEAE: *Valeriana officinalis*, *pauciflora*
- DIPSACACEAE: *Dipsacus sylvestris*
- CUCURBITACEAE: *Sicyos angulatus*, *Echinocystis lobata*
- CAMPANULACEAE: *Specularia perfoliata*, *Campanula americana*, *aparinoides*
- LOBELIACEAE: *Lobelia cardinalis*, *siphilitica*, *spicata*, *inflata*
- COMPOSITAE: *Vernonia noveboracensis*, *fasciculata*, *altissima*, *Eupatorium purpureum*, *serotinum*, *altissimum*, *sessilifolium*, *perfoliatum*, *urticaefolium*, *coelestinum*, *Solidago caesia*, *latifolia*, *bicolor*, *ulmifolia*, *nemoralis*, *canadensis*, *graminifolia*, *Aster divaricatus*, *novae-angliae*, *azureus*, *Shortii*, *cordifolius*, *Lowricanus*,

sagittifolius, *turbinellus*, *laevis*, *ericoides*, *multiflorus*, *dumosus*, *Tradescanti*, *Erigeron pulchellus*, *phildelphicus*, *vernus*, *annuus*, *ramosus*, *canadensis*, *divaricatus*, *acris*, *Antennaria plantaginifolia*, *Gnaphalium polycephalum*, *Inula Helenium*, *Polymnia canadensis*, *Ambrosia trifida*, *artemisiifolia*, *Xanthium canadense*, *Heliopsis helianthoides*, *scabra*, *Eclipta alba*, *Rudbeckia triloba*, *hirta*, *laciniata*, *Helianthus annuus*, *laetiflorus*, *mollis*, *microcephalus*, *doronicoides*, *divaricatus*, *hirsutus*, *strumosus*, *decapetalus*, *Actinomeris alternifolia*, *Bidens frondosa*, *connata*, *cernua*, *bipinnata*, *trichosperma*, *Galinsoga parviflora*, *Helenium autumnale*, *Dyssodia papposa*, *Achillea*

Millefolium, *Anthemis Cotula*, *Chrysanthemum Leucanthemum*, *Parthenium*, *Tanacetum vulgare*, *Artemisia Abrotanum*, *Absinthium*, *Erechtites hieracifolia*, *Cacalia reniformis*, *atriplicifolia*, *Senecio aureus*, *Arctium minus*, *Cirsium lanceolatum*, *discolor*, *altissimum*, *muticum*, *arvense*, *Centaurea Cyanus*, *Cichorium Intybus*, *Krigia virginica*, *amplexicaulis*, *Tragopogon porrifolius*, *Taraxacum officinale*, *erythrospermum*, *Sonchus oleraceus*, *asper*, *Lactuca scariola*, *canadensis*, *integrifolia*, *hirsuta*, *villosa*, *floridana*, *spicata*, *Pyrrhoppappus*, *carolinianus*, *Prenanthes alba*, *altissima*, *Hieracium venosum*, *paniculatum*, *scabrum*, *Gronovii*

OBSERVATIONS ON THE TERATOLOGY OF THE
GENUS CUSCUTA.

T. G. YUNCKER, DePauw University.

Examination of thousands of specimens of the genus *Cuscuta*, representing all the known species, has shown that this group does not commonly show monstrosities. However, some irregularities of structure have been observed which are briefly described below. Little mention of this genus has been found in discussions on teratology. Penzig¹ mentions forms having pistils with three styles and states that four- and six-parted flowers are common, but I find six-parted flowers to be very rare in the many specimens which I have dissected. Engelmann² says: "I have seen very few abnormal irregularities in the flowers of *Cuscuta*. Sometimes one or more segments of the corolla are partially or entirely changed into a stamen, and the capsule is occasionally three- or four-carpellary, instead of two-carpellary."

Normally, the flowers of *Cuscuta* are four- or five-parted, perfect, gamopetalous, mostly gamosepalous, hypogynous, and sessile in compact, glomerulate or spicate clusters, or more or less pedicellate in cymose, umbellate, racemose, or paniculate inflorescences. A set of appendages (scales) opposite the stamens and alternating with the corolla lobes, mostly laterally united to form a corona, and more or less adherent to the inner surface of the corolla, is present in the majority of the species. The pistil is two-celled, each cell containing two anatropous ovules. The styles are two, distinct, or more or less united, with capitate, conic, ligulate, clavate, or elongated-filiform stigmas. In the compact glomerulate clusters of some species the several flowers of the cluster are borne in the axis of a single bract, while the loose, more branching forms commonly bear each flower in the axis of a bract.

In *C. cuspidata* there are many bracts in the loose inflorescence which, other than those containing flowers, support at most only rudimentary buds. A specimen collected by Deam in southern Indiana showed an excessive production of bracts and the almost entire absence of flowers (fig. 1. See also Yuncker³). Another specimen, possibly *C. sandwichiana*, exhibiting somewhat similar excessive bract production and the suppression of the flowers, was collected by Degener in Hawaii. In this the inflorescence is entirely converted into a mass of overlapping bracts in the axils of some of which are found miniature buds (fig. 2). A specimen of *C. monogyna* collected by Haussknecht in Asia Minor, and given the varietal name of *prolifera*, displayed a strik-

¹ Penzig, O., *Pflanzen Teratologie* 3:70. 1922.

² Englemann, G., *Amer. Journ. Sci. and Arts* 43:236. 1842.

³ Yuncker, T. G., *Amer. Bot.* 27:48, fig. 2, 1921.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

ing proliferous development. No flowers were formed and in their place were numerous bract-like scales from amongst which the branches were developed (figs. 9 and 10). Several inflorescences in a collection of *C. odontolepis* showed the branches of the inflorescence arising from what appeared to be a normal calyx in place of the bract which is normally present (fig. 7).

The flowers in this genus normally originate exogenously, but endogenously formed flowers seem to be usual for *C. glomerata* (see Bessey).⁴ They have also been observed to a lesser degree in *C. compacta* and still less frequently in *C. cephalanthi* and a few other species. This condition, so far as observed, however, appears to be present only in the sub-genus *Grammica* (i. e. those with capitate stigmas).

While five-parted flowers is the common and apparently typical condition for the genus, several species have regularly four-parted flowers. Three- and four-parted flowers are not uncommon in those species normally five-parted, and three- and five-parted forms are also commonly seen in those species regularly four-parted. Only one or two six-parted flowers, however, have been observed, and it is believed that this condition is extremely rare.

In *C. Purpusii* (fig. 5) and *C. Boldinghii* well formed buds were found between the calyx and the corolla, while in *C. andina* (fig. 3) three well formed lobes of a second calyx within the normal outer one were observed.

A specimen each of *C. Suksdorfii* (fig. 4) and *C. abyssinica* displayed a bifurcated corolla lobe, which, had the cleft been deeper, would have produced a six-lobed corolla. A specimen of *C. planiflora* showed a similar cleft in one of the calyx lobes. The corolla lobes of a specimen of *C. Pringlei* (fig. 11) were cupped at their tips to an extreme degree.

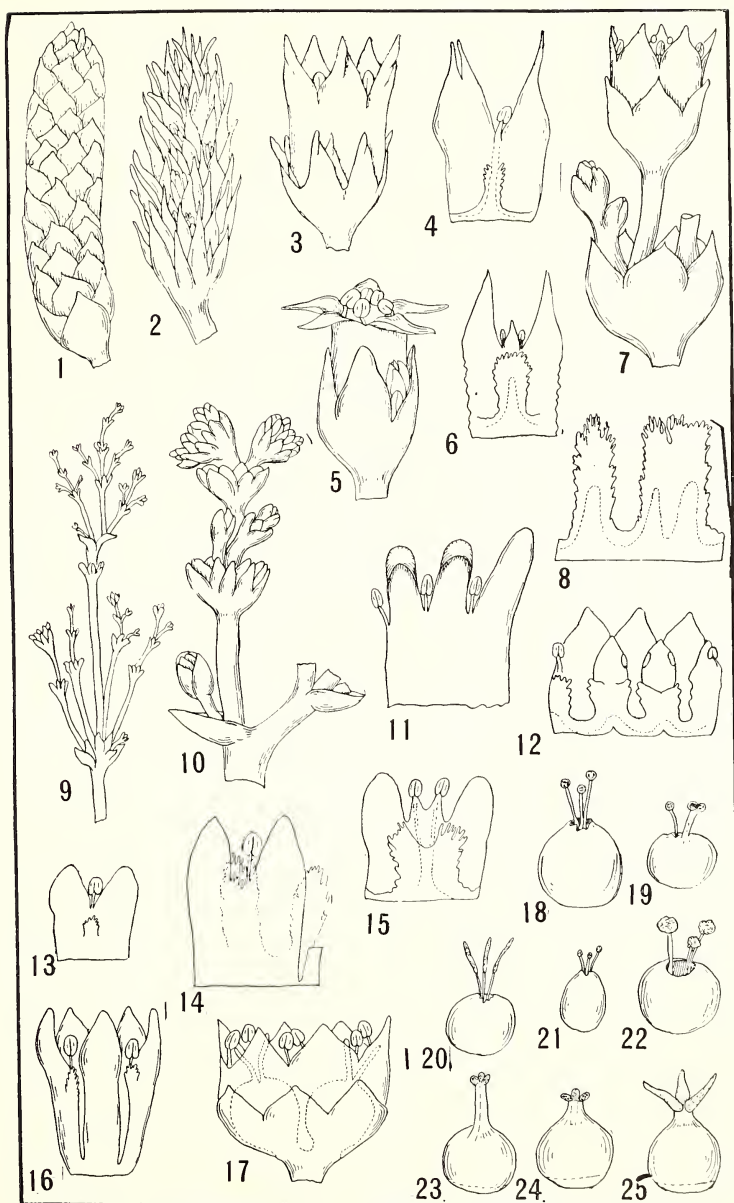
Rarely are the scales united with each other excepting in the lower (bridged) part, but in a collection of *C. Gronovii calyptrata* some of the scales were found to be completely united with each other (fig. 8). In *C. platyloba* (fig. 13), *C. Pringlei*, *C. suaveolens* (figs. 14 and 16) and *C. stenoloba* an extra set of scales were present on the outside of the corolla opposite the stamens. Normal scales were also present within the corolla. Robbins and Egginston⁵ also show this condition in *C. indecora*. This, however, is a very unusual condition. The corollas of some flowers in a specimen of *C. suaveolens* were cleft nearly to the base (fig. 16).

Very few abnormalities of the stamens were seen. In some, *e. g.* *C. lucidicarpa* (fig. 12), the connective was broadened and petaloid. In one specimen of *C. salina* (fig. 6) a small petal-like projection between two miniature stamens was found. In one or two flowers globular, capitate anthers were noticed. In a specimen of *C. obtusiflora glandulosa* double stamens were seen as shown in figure 15.

Three styles and three stigmas are very common in the genus, almost every species exhibiting this abnormality (figs. 18 to 25).

⁴ Bessey, C. E., Amer. Nat. 18:1145-1147. 1884; 19:996-997. 1885; 20:278-279. 1886; Science 6:225. 1885.

⁵ Robbins and Egginston, Colorado Agr. Exp. Station Bull. 248:7, fig. 4. 1918.



Figs. 1-25—See page 338 for explanation.

Choisy⁶ pictures a pistil of *C. Gronovii* with three styles, two of which are shown grow together. Three-styled pistils are also mostly three-celled. One of the most unusual abnormalities observed was in a specimen of *C. epithymum Kotschyi* (fig. 17) which showed a six-parted flower containing two distinct and apparently normal pistils each of which contained four seemingly normal ovules.

EXPLANATION OF FIGURES.

Fig.

1. *C. cuspidata*, showing inflorescence composed entirely of bracts;
2. *C. sandwichiana?*, with excessively bracteate inflorescence and with the flowers mostly abortive;
3. *C. andina* with a double calyx;
4. *C. Suksdorfii* showing a bifurcated corolla lobe;
5. *C. Purpusii* with buds between the calyx and the corolla;
6. *C. salina* with two miniature stamens separated by a small, petal-like projection;
7. *C. odontolepis* showing proliferation in inflorescence;
8. *C. Gronovii calyptrata* with united scales;
9. *C. monogyna* showing proliferation of inflorescence;
10. Part of figure 9 enlarged to show details;
11. *C. Pringlei* with cupped tips of corolla lobes;
12. *C. lucidicarpa* showing petaloid connective of stamens;
13. *C. platyloba* with scales on the outside of the corolla;
- 14 and 16. *C. suaveolens* showing extra scales on outside of the corolla and a deeply cleft corolla;
15. *C. obtusiflora glandulosa* with doubled stamens;
17. *C. epithymum Kotschyi* with a 6-parted, 2-pistillate flower;
18. *C. Gronovii* with three styles;
19. *C. platyloba* with three styles, two of which are grown together;
20. *C. epithymum* with three styles;
21. *C. salina* with three styles;
22. *C. racemosa* with three styles;
23. *C. lupuliformis* with three styles;
24. *C. cassytoides* with three styles;
25. *C. reflexa* with three styles.

⁶ Choisy, J. D., Mém. Soc. Phys. Hist. Nat. Genève 9:Pl.IV, fig. 3, 1841.

HOLDFAST CELLS IN SPIROGYRA.

FREDDA DORIS REED, Chicago, Illinois.

In the summer of 1925 Doctor Land of the Department of Botany, University of Chicago, was collecting for *Ulothrix* in the lagoon in Jackson Park. Growing on the rocks in the place where he was accustomed to find *Ulothrix* was some *Spirogyra* which he took to the laboratory and turned over to the writer. Upon examination the *Spirogyra* was found to have well developed holdfast cells by means of which it was quite firmly attached to the rocks.

The material was scraped from the rock, killed in chromo-acetic acid, stained in Haidenhain's iron-alum haematoxylin and run up into Venitian turpentine from which it was mounted. A subsequent examination of the mounts revealed slight variations in the holdfast cells and some interesting abnormalities in the structure and character of the chloroplasts.

As a rule the holdfast cells are longer than the ordinary vegetative cells of the filament. From the basal end extend rhizoid or haustoria-like appendages; these structures seem to originate from the peripheral region of the cell rather than from the end and are somewhat contorted and twisted but in general spread out over the rock. They vary in number and in length and they may or may not be branched. Figure 1, A, B, and C, gives an idea of the size of these rhizoid-like structures as compared with the rest of the cell.

The four chloroplasts have almost lost their spiral character: on the contrary they extend more nearly as straight ribbons down through the center of the cell as if they had been stretched and pulled out of shape. In some cases portions of the chloroplasts may be found down in the rhizoids.

In one filament there were two holdfasts; not only the basal cell but the one adjacent as well had developed rhizoids. The rhizoids in the latter apparently developed after those in the lower cell as a result of the stimulus furnished by coming in contact with the substratum or any resisting substance. Such a contact was made by the bending of the filament. Figure 1, D is a diagram of this filament and E and F are drawings showing the holdfasts and the character of the chloroplasts in these two cells.

Since finding the material described above, other collections of *Spirogyra* have been made which showed holdfast cells. These collections were made at different seasons of the year and taken both from running water and quiet ponds. Therefore it seems quite evident that the formation of such cells is not dependent on the habitat. It may be that the lower cell, resulting from the first division of the zoospore, develops into a holdfast and the filament later breaks away and becomes

a free-floating form. This would account for the fact that we do not ordinarily find them. Or, again, it may be that the development of the holdfast is a response to an external stimulus such as proximity to some resisting substance. The fact that cells other than the basal one may develop rhizoids would support this latter view. In any event this *Spirogyra* illustrates two fundamental principles; first, the cells are all morphologically and potentially alike in the beginning, and have plasticity which gives them the ability to respond to stimuli; and, second, diversion of tissue, represented by cell elongation and the abnormal position of the chloroplasts, is apparently due in this instance to a mechanical stress and strain exerted by the constant buoyancy of the water.

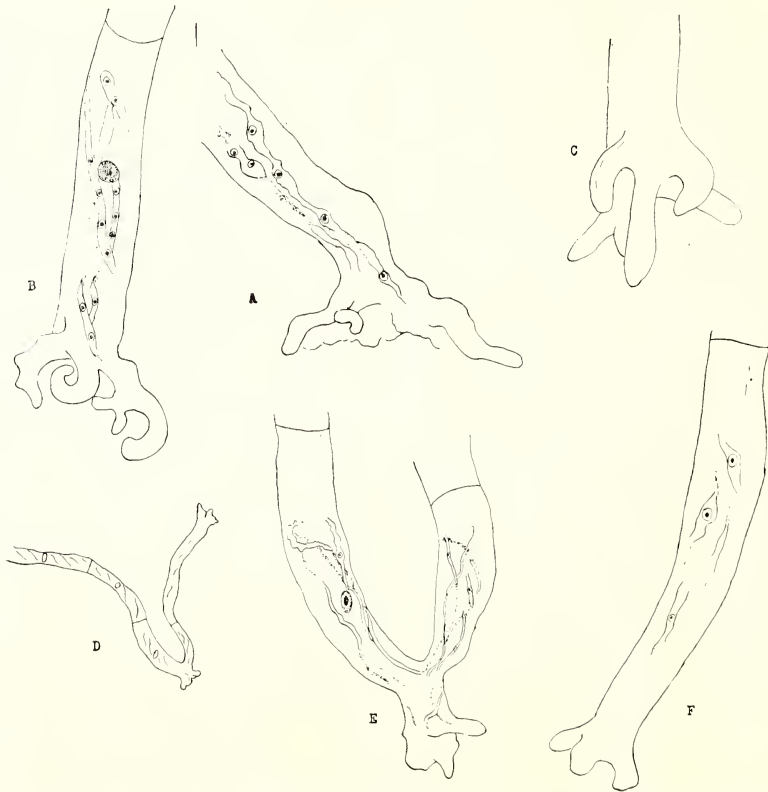


Fig. 1—A, B, and C, typical basal cells showing twisted and branched rhizoids and the almost straight bands of chloroplasts. D, diagram of filament with two holdfast cells. E and F, two holdfast cells shown in D.

PLANT DISEASES IN A HOME GARDEN.¹

E. B. MAINS, Purdue Agricultural Experiment Station.

The culture of flowering plants offers varied attractions. To some, it is the esthetic, the harmonious combination of form and color. To the collector, it is the multitude of varieties and species which he is able to bring together. To the culturist, it is the challenge of his skill, the discovery of the needs of various plants and their successful culture. To the breeder it is the possibilities for improvement by the combination of qualities through hybridization and selection. Often these interests are combined to a more or less extent. Usually, however, the diseases of plants awaken no interest other than that demanded by the necessity for their control. To a plant pathologist, however, the disease itself is of great interest. While he has the control of disease as the end in view, at the same time he is interested in the cause of the disease, the effect produced, the effect of environment conditions on its development, all problems challenging his curiosity and ingenuity and having important bearing on control.

It thus happens that the writer, as a pathologist, has an added interest in his flower gardening. While the gardener's interest has for the most part predominated, those of a pathologist have played a part, resulting in some observations which may be of interest to both gardeners and pathologists.

The following observations were made, for the most part, during 1926 and 1927 in a small garden, approximately 60 by 75 feet, in West Lafayette, Ind. This garden was started in the fall of 1925 so that there was no accumulation of diseases as might result in an older garden. Only the precautions against disease taken by the average gardener were practised. The situation, therefore, was similar to that which might occur in almost any small home garden.

CHINA ASTERS, *Callistephus chinensis*

Yellows. This disease was very abundant on China asters in 1924 resulting in a number of plants showing a shortening of the flower stalk, contortion and yellowing of the upper leaves, excessive branching and malformation of the flower heads. Plants of a species of *Erigeron* showed similar symptoms, and were probably the source of the disease. Kunkel² has shown that this disease, which is caused by a virus, winters over in biennial species of such genera as *Erigeron*, *Sonchus*, *Chrysanthemum*, *Asclepias*, *Plantago*, from which the virus is spread to asters

¹Contribution from the Department of Botany, Purdue University Agricultural Experiment Station.

²Kunkel, L. O. Studies on Aster Yellows. *Am. Jour. Bot.* 13:646-705. 1926.

"*Proc. Ind. Acad. Sci.*, vol. 37, 1927 (1928)."

by leaf hoppers. He found no evidence of seed carriage. When this disease is present it is usually very serious, not only affecting the appearance of the plant but greatly reducing the blossoming. Kunkel recommends the removal and destruction of all weed hosts and diseased asters and spraying or dusting of healthy plants with nicotine or other insecticides to kill leaf hoppers.

Wilt. A slight wilting of asters was noted in the summer of 1924. A few blossoming plants showed a wilting of the lower leaves. There was a longitudinal brown streaking of the stems of such plants. The wilt progressed upward until the plants were dead. This disease is caused by *Fusarium conglutinans* var. *Callistephi*. It can persist in the soil for a number of years. Gloyer³ states that the disease is seed carried. Jackson⁴ recommends treating the seed with mercuric chloride 1:1000. Soil for seedling beds should either be steam sterilized or treated with mercuric chloride 1:1000 or formaldehyde 1:50. Mercuric chloride 1:2000 (*l.c.* 3) used on beds of seedlings showing infection, was found to check the disease. All diseased plants should be removed and destroyed and the beds should be soaked with formalin 1:50 to a depth of 10 inches before planting with asters again (*l.c.* 4).

Rust. The Rust of China asters, *Coleosporium Solidaginis*, was noted in 1925, 1926, and 1927. It appeared rather late in the season, usually in September. No very serious damage has been noted. It,



Fig. 1.—The rust of China asters, *Coleosporium Solidaginis*.

³ Gloyer, W. O. Fungous Diseases of the China Aster. (Abstract) *Phytopath* 14:64. 1924.

⁴ Jackson, A. B. The *Fusarium* Wilt of China Asters. *Sci. Agr.* 7:233-247. 1927.

however, affects the appearance of the plants, covering the leaves with the orange uredinia (fig. 1) and causing heavily infected leaves to turn yellow and die, a condition very undesirable for an ornamental.

This species of rust has been shown to live over winter on perennial species of *Solidago* (5, 6) and probably spreads from *Solidago* and wild asters to China aster.

Apparently differences in the susceptibility of China asters to this disease occur. A strain of Comet yellow was noted showing only a trace of the rust while the lower leaves of the surrounding plants were yellow. It is probable that resistant strains of asters can be developed by proper selection. Judging by the results obtained with other rusts this disease can probably also be controlled by dusting with sulphur.

BUTTERCUP, *Ranunculus septentrionalis*

Leaf Spot. A leaf spot caused by *Didymaria didymia* was very abundant during August and September on *Ranunculus septentrionalis*. The leaves showed many angular brown spots covered on the lower side with the white mass of conidiophores. The infection was so severe that many of the leaves were killed. Plants of *R. acris* and *R. repens* var. *flore pleno*, growing intermingled with the diseased plants of *R. septentrionalis*, showed no signs of disease.

DELPHINIUM.

Powdery Mildew. The powdery mildew of Delphinium, *Erysiphe polygoni*, developed to a slight extent during the late summer of 1927. Other than a slight mildewing of the lower leaves it caused no damage. It can be controlled by dusting with sulphur.

GLADIOLUS.

Scab. This very prevalent disease of Gladiolus, due to *Bacillus marginatus*, was noted during the summer of 1927 in the varieties Mrs. Frank Pendleton, Crimson Glow and America. It was severe on only a few plants. The infection first appeared on the leaves as reddish spots in early summer. As these spots enlarged, they became darker. With the death of the leaf bases, the leaves turned brown and the plants broke over without forming flower spikes. The corms of the infected plants showed a few dark brown pits from which the disease derives its name. The corms from infected plants were much smaller and produced very few bulblets. Miss McCulloch⁷ recommends the treatment of diseased corms before planting with either mercuric chloride (1:1000) or formalin (1:80). The corms should first be soaked in water for 15 minutes and then allowed to stand for several hours in a moist condition

⁵ Mains, E. B. The Wintering of *Colcosporium Solidaginis*. Phytopath. 6:371-372. 1916.

⁶ Clinton, G. P. Report of the Botanist for 1907. *Colcosporium Solidaginis* Conn. Agr. Exp. Sta. Rep. 1907. pt. 6. 375-380. 1908.

⁷ McCulloch, Lucia. A Leaf and Corm Disease of Gladioli Caused by *Bacterium marginatum*. Jour. Agr. Res. 29:159-177. 1924.

to soften the bacterial exudate. They should then be soaked for one-half hour in the mercuric chloride or formalin solution. They can either be planted at once or allowed to dry and planted later.

GOURD, *Curcubita* sp.

Mosaic. In the spring of 1927 a packet of mixed gourds was planted along a boundary fence. While they were still small, mosaic appeared and spread rapidly, killing most of the plants before they were six inches high. A few reached a length of three feet but showed the typical mottling of mosaic diseases. Only a few flowers developed on these vines and no fruits were formed.

HOLLYHOCK, *Althaea rosea*

Cercospora Spot. The leaf spot of hollyhocks caused by *Cercospora althaeina* was prevalent during 1926 and 1927. It caused a brown angular leaf spot about one-eighth to one-quarter of an inch in diameter (fig. 2). No serious damage resulted, although heavily infected leaves

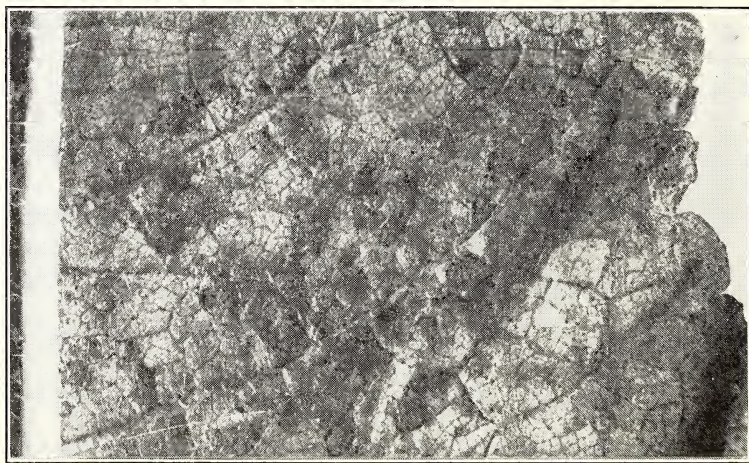


Fig. 2.—Leaf spot of hollyhocks showing the brown angular areas produced by *Cercospora althaeina*.

turned brown and died. The spotting, however, is an undesirable condition for an ornamental. While most of the plants showed heavy infection on the lower leaves, two plants among them showed only a slight infection. Probably resistant strains can be developed by proper selection.

Rust. Although the rust of hollyhocks, *Puccinia Malvacearum*, has been noted in West Lafayette for a number of years, it first appeared in the writer's garden in the spring of 1927. Judging from the inquiries which have been received from over the state, this season has been very

favorable for the development of this disease, being for the most part unusually cool and wet. By June a number of the plants in the writer's garden were so severely rusted that many of the lower leaves were killed and the upper ones covered with the dark brown cushion shaped telia which turned white following the germination of the spores. During July and August there was a moderate development of the rust. With the hot weather of early September it was greatly retarded, the new leaves being relatively free. With the return of cool weather the disease again developed rapidly and by the end of October the older leaves of susceptible plants were covered with telia. Several plants, however, were very noticeable on account of their freedom from rust, (fig. 3), although



Fig. 3—Differences in susceptibility to hollyhock rust, *Puccinia Malvacearum*, the leaf to the right from a heavily rusted plant, the leaf to left from an adjacent slightly rusted plant.

surrounded by heavily rusted plants. By proper selection resistant lines can probably be developed. The rust has been shown to overwinter on the hollyhock plants and it is well to collect and destroy the old rusted leaves in late fall or very early spring. Dusting with sulphur should be effective in helping to control this disease.

IRIS

Leaf Spot. During 1926 and 1927 the leaf spot, *Didymellina Iridis* (*Heterosporium gracile*) has been the most prevalent disease of iris in the writer's garden. It first appeared following flowering as scattered spots varying from one-fourth to three-fourths of an inch in diameter. The center at first is light colored, later showing black conidiophores and

a brown encircling ring (figs. 4 and 5). This disease not only makes the plants unsightly during the summer and fall but it must also considerably weaken susceptible varieties if they are defoliated for several years in succession.

There are evidently considerable differences in susceptibility between varieties. The most susceptible varieties showed a rapid development of

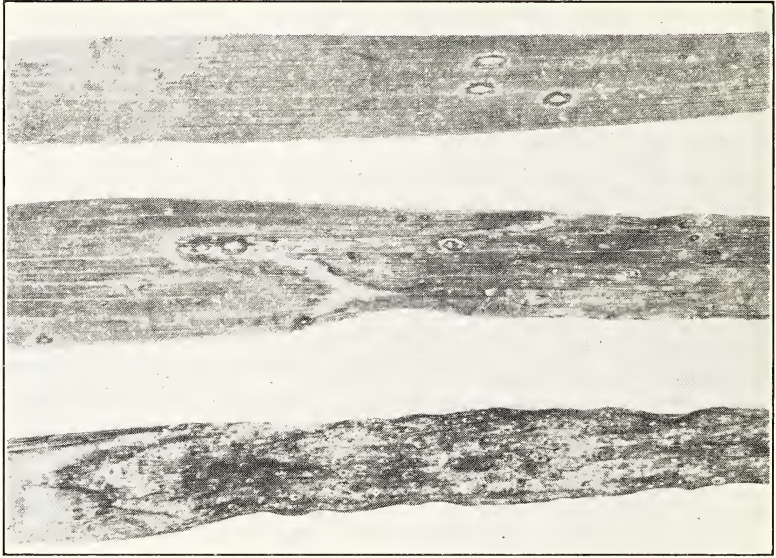


Fig. 4--The leaf spot of Iris, *Didymellina Iridis*, showing different stages of infection from a few diseased spots at the top to a leaf almost completely killed at the bottom.



Fig. 5—Leaf spot of Iris showing the light colored center with black conidiophores.

the disease. The spots were large and abundant and the leaves were mostly killed by the last of August or September. Moderately susceptible varieties showed a slower development of the disease, often-times only the upper half of the leaves being killed by September. The slightly susceptible varieties showed very little development of the disease, the leaves, except for a few spots, remaining green. Some of the species of iris were extremely resistant, showing no effect whatever. Among the varieties of iris the following showed heavy infection (Fig. 6): Mrs. Neubronner, Iris King, Mrs. Darwin, Lent. A. Williamson, May Queen, Nine Wells, White Knight, Beethoven, Gypsy Queen, Perfection, Honorable, Blue Boy, Sherwin Wright, Storm Cloud, Mary Garden.

The following showed moderate infection: Loreley, Dr. Bernice, James Boyd, Her Majesty, Mithras, Blue Jay, Queen Alexandra, Quaker Lady, Parc de Neuilly, Carthusian, Albert Victor, Purple King, Madame Chereau, Jacquesiana, Flavescens, Aurea, Rhein Nixe, Parisiana, Lohengrin, Celeste.

The following showed only a slight infection (fig. 6): Amas, Albicans, Juniata, Violacea grandiflora, Caprice, Monsignor, Fairy, Pallida dalmatica, Florentina alba, Ballerine, Georgia, Queen Caterina, Powhatan.



Fig. 6—Differences in susceptibility of Iris varieties to leaf spot. To the left a plant of the variety, Mary Garden, with leaves almost completely killed; to the right, Fairy, showing only a slight infection.

Of the Iris species *I. dichotoma* was heavily infected and *I. tectorum* moderately infected while *I. versicolor*, *I. halophila* and *I. pumila cyanea* showed only a slight infection. The species *I. siberica*, *I. fulva*, *I. pseudacorus*, *I. xiphium*, *I. xiphioides*, *I. Kaempferi*, *I. lacustris* and the variety Dorothea K. Williamson, a cross between *I. fulva* and *I. foliosa*, showed no infection.

Some writers⁸ consider that this disease is favored by poor conditions of growth and recommend treatment with lime and phosphates to increase the vigor of the plant. The fungus lives over winter on the dead iris leaves and Tisdale⁹ has found that the removal of the dead leaves in early spring was very effective in checking this disease.

⁸ Hoare, A. H. Iris Diseases. Jour. Min. Agr. 32:454-458. 1925.

⁹ Tisdale, W. B. Iris Leaf Spot Caused by *Didymellina Iridis* Phytopath. 10:148-163 1920.

Soft Rot. In both 1926 and 1927, soft rot was very troublesome on a few varieties. This disease which is apparently due to *Bacillus carotovorus*¹⁰ attacks the rhizomes, flower stalks and leaves, reducing them to a pulpy, ill-smelling mass. It has been most prevalent about flowering time and was especially severe on the varieties Queen Caterina and Quaker Lady. The disease may be considerably retarded by soaking soil and rhizomes with organic mercury compounds as soon as infection is noted. If the disease has gained considerable headway it is best to dig the plants, clean away the decayed portion, soak in mercury compounds or with a pink solution of potassium permanganate and reset in a new location.

Sclerotial Rot. Another rot of the rhizomes and leaf bases is caused by a species of *Sclerotium*. During the summer of 1927 the variety *Pallida dalmatica* showed infection. The rhizomes and leaf bases are covered with a white mass of mycelium which produces abundant light brown sclerotia (fig. 7).



Fig. 7—Sclerotial rot of *Iris* showing the dead leaf bases with mycelium and sclerotia of the fungus.

GOLDEN-BANDED LILY, *Lilium auratum*

Botrytis Blight. In the spring of 1926, two stalks of *Lilium auratum* showed a blight which resulted in the rapid dying of leaves and stalk, apparently caused by a species of *Botrytis*. Since it was evident that the disease would follow the stem down into the bulbs, the plants were dug and the stalks cut off. The bulbs were then dusted with sulphur and reset in another location. Although the bulbs were unable to store much

¹⁰ Richardson, J. K. A Study of Soft Rot of *Iris*. Ann. Rep. Quebec Soc. Prot. Plants 15:105-120. 1923.

food in 1926, they each produced a short flower stalk with three well developed flowers in 1927 and showed no signs of disease. A plant of *L. tenuifolium* showed a similar infection in 1927. This was not treated and when dug in the fall the bulb of the infected plant was found to be rotted.

PEONY, *Paeonia* spp.

Blight. During the spring of 1927, a blight of peony due to *Botrytis Paeoniae* was responsible for the blasting of a few buds.

Leaf Spot. A leaf spot due to *Phyllosticta commonsii* was noted during the late summer of 1927. It caused very little damage other than the effect on the appearance of the plants.

PETUNIA

Mosaic. Among a number of plants of giant ruffled petunia purchased in the spring of 1927, several showed the mottled and contorted leaves, characteristic of mosaic diseases. These all died before midsummer.

HARDY PINK, *Dianthus Allwoodii*

Anthracnose. About the middle of the summer of 1927, several plants of *Dianthus Allwoodii* showed a yellowing of the leaves of some of the lower branches. As the disease progressed the lower branches died and the leaves of upper branches turned yellow. Fruiting bodies of *Volutella Dianthi* (fig. 8) appeared upon the dying branches. The disease was also noted slightly infecting a plant of *D. Caesius*, Cheddar Pink.



Fig. 8—Anthracnose of pinks, *Volutella Dianthi*, showing the fruiting bodies of the fungus on a dying stem.

ROSES, *Rosa* spp.

Black Spot. This disease caused by *Diplocarpon Rosae* (*Actinonema Rosae*), appeared as black spots on the leaves of some hybrid teas. Besides the unsightly appearance caused by the spotted foliage considerable damage may occur on account of the defoliation which results. The fungus lives over winter in the fallen leaves so that it is important that all infected leaves should be gathered and destroyed. For the control of this disease, Massey¹¹ recommends dusting with sulphur at weekly intervals, starting as soon as the first leaves are well out.

Powdery Mildew. This common mildew of roses, *Sphaerotheca pannosa rosae*, was severe on the variety Dorothy Perkins in the fall of 1927. The leaves were covered with the white powdery mat of mycelium and conidiophores. Many of the leaves were contorted and variously deformed and some of the young growing tips were covered with the fungus. While the plants were not noticeably injured they were unsightly. Dusting with sulphur as soon as the disease appears will prevent its development.

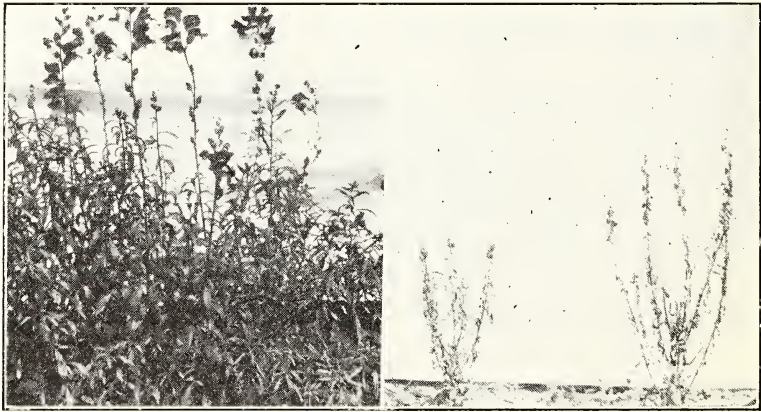


Fig. 9—Control of snapdragon rust by sulphur. Plants at left were dusted with sulphur and are free from the disease. At right, plants not dusted and killed by the rust.

SNAPDRAGON, *Antirrhinum majus*

Rust. For a number of years snapdragon rust, *Puccinia Antirrhini*, has been more or less prevalent in the garden. It has usually appeared about midsummer, apparently being blown from infected plots of a nearby florist. The rust infects the leaves, producing large dark brown, powdery uredinia on the lower surface and causing their premature death. On the stems, it produces large uredinia and oftentimes girdles the stem, causing the death of the upper portion. In cases of severe infection the plants may be entirely killed early in the season.

¹¹ Massey, L. M. Black-Spot and Mildew of Roses. *Am. Rose Ann.* 1922:77-86.

The rust may occasionally overwinter in the uredinal stage if the infected host remains alive. In this locality, this very seldom occurs. Such plants should be destroyed. The rust is apparently heteroecious¹² and the alternate host probably does not occur in this region, so that the teliospores are probably functionless. If plants are started from seed there is little or no chance of this disease unless the rust is carried over winter in the uredinal stage either on overwintering plants outdoors or in greenhouses. There is some evidence that this disease may be controlled by resistant selections.¹³ Dusting with sulphur (fig. 9) is also a very effective means for the control of this rust (*l.c.* 13).¹⁴

STAR OF BETHLEHEM, *Ornithogalum umbellatum*

Rust. Star of Bethlehem may serve as the aecial host of the barley leaf rust, *Puccinia anomala*.¹⁵ When some plants of Star of Bethlehem were covered during the winter of 1926-1927, with barley straw bearing telia of this rust, aecia were produced on the young leaves in the spring. This rust will occur only when leaf-rusted barley straw is in the vicinity.

In 1925 another rust was discovered on Star of Bethlehem under very interesting circumstances. In the fall of 1924 an order of bulbs of Glory-of-the-Snow and Snowdrops were planted together. In the spring of 1925, Mrs. Mains called my attention to a rust on one plant which appeared to differ from the rest. This proved to be *Ornithogalum umbellatum* and the rust was found to be *Puccinia Liliacearum*. As far as I can determine this rust has never been noted before in North America. It occurs rather commonly in Europe. The rust is autoecious producing only teliospores which reinfect the *Ornithogalum* in the spring, and probably occurred on some leaf parts adhering to the bulb and was thus brought into this country from Holland. The infected plant has been watched for two years but the rust did not reappear and apparently has died out.

SWEETPEAS, *Lathyrus odoratus*

Black Root Rot. In the spring of 1926, attention was attracted to a few plants of sweetpeas which showed a stunting and considerable yellowing. An examination of the roots showed a black rotted condition. This was caused by *Thielovia basicola*.

Powdery Mildew. Powdery mildew, *Erysiphe Polygoni*, was prevalent on sweetpeas during the summers of 1926 and 1927. In late summer the foliage was covered with the white mycelium and spores and

¹² Mains, E. B. Notes on the Life-History of the Snapdragon Rust, *Puccinia Antirrhini*. Phytopath. 6:281-287. 1924.

¹³ Mains, E. B. and Thompson, Dorothy, Snapdragon Rust. *Puccinia Antirrhini* (Abstract) Phytopath. 18: Jan. 1928.

¹⁴ Butler, O. Experiments on the Field Control of Snapdragon Rust together with a Description of a Method for the Control of the Disease in the Greenhouses. N. Hamp. Agr. Exp. Sta., Tech. Bull. 22. 1923.

¹⁵ Mains, E. B. and Jackson, H. S. Aecial Stages of the Leaf Rusts of Rye, *Puccinia dispersa*, and of Barley, *P. anomala*, in the United States. Jour. Agr. Res. 28:1119-1126. 1924.

many of the leaves turned yellow and fell off. Dusting with sulphur is a control for this disease.

TULIPS, *Tulipa* spp.

Botrytis Blight. Although we have been growing tulips for the past six years, practically no trouble was experienced until the spring of 1926. In 1926 and again in 1927 the botrytis blight, caused by *Botrytis Tulipae*, was severe. Both seasons were very wet and this probably accounted for the severity of the disease. Practically all parts of the plant may be affected. The disease first appears as small yellowish spots on the leaves which as they enlarge become reddish brown and finally covered by a gray mass of conidiophores. The flowers are somewhat similarly affected. When the infection appears early the flower buds are often blasted. On the bulb yellow or brown lesions are produced on the outer white bulb scale beneath the outer brown coating. Small black sclerotia are often produced on this outer covering. While all the varieties in the garden showed some infection, the varieties Picotee, Gesneriana ixioides, Cardinal Manning, La Merveille, William Pitt, Vermillion Brilliant, and Mon Tresor were the most severely infected, Pride of Haarlam, Mr. Farncombe Sanders, Mrs. Moon, Clara Butt, Lucifer, Golden Bronze, Orange King, Flamingo, showing only a moderate to slight amount of infection.

The studies of Hopkins¹⁶ indicate that *Botrytis Tulipae* is specific to tulips. The disease is probably introduced with infected bulbs. The plants developing from these in the spring produce spores which infect neighboring plants. Hopkins recommends the removal and destruction of diseased plants as soon as they appear to avoid the secondary spread to healthy plants.

Diseases of Unknown Cause. A number of other plants were diseased but time was not available for a determination of the causes. In 1926 practically all the plants of Clarkia and Godetia were killed. Several plants of St. Brigids Anemone were killed by a root rot. In the seedling beds both in 1926 and 1927 nearly all of the seedlings of Perennial Flax, Iceland Poppy and Primrose damped off. In the late summer of 1926 several plants of the Yellow Ladyslipper were heavily infected with a leaf spot. Following hot weather in September, 1927, a number of the flower buds of dahlia were blasted (Fig. 10) whether by the hot weather or due to a fungus disease was not determined. A Penicillium was isolated but this was probably secondary. A number of leaf spots of peony, delphinium, lily of the valley were present to a slight extent. Doubtless if an intensive survey had been made a number of others would have been found. It is evident that there is no shortage of pathological problems when this number of diseases occur in such a small area.

While most of the diseases mentioned are apparently of minor importance as far as the effect on the development of the host is con-

¹⁶ Hopkins, E. T. The Botrytis Blight of Tulips. Cornell Agr. Exp. Sta., Mem. 45. 1921.

cerned they are all undesirable in an ornamental garden since they are unsightly. Each, of course, presents a problem in itself. On account of the more pressing economic problems engaging public funds, most of the minor diseases will probably not receive much attention for some time. Those who are particularly interested in the lesser grown ornamentals should attempt to solve some of these problems themselves.

The eradication of a disease may not always be the best in the long run. The process may have to be continuously repeated. If there is



Fig. 10—Blighted buds of dahlia following hot weather in September. The flower to the left from a late bud. The blasted heads to the right from early buds which never opened.

any evidence of differences in susceptibility to a disease, the plants which survive may be of considerable importance. From such plants it may be possible to breed varieties resistant to the disease. To do so successfully the disease must be present in a severe form for a number of generations in order that the susceptible individuals may be eliminated. As Prof. L. R. Jones¹⁷ has stated: "Disease resistant plants are all about us awaiting detection. Variations as to relative susceptibility, or conversely, as to relative resistance to disease, occur as commonly as do variations in other characteristics." In the two years of observation noted above there is evidence of resistance of hollyhocks to rust and *Cercospora*, Asters to rust and Iris to leaf spot. Professor Jones points out that in the development of our cultivated plants, the amateur has played a large part and that it is the amateur breeder, stimulated by the satisfaction of accomplishment rather than hope of financial rewards, upon whom the burden of plant improvement by disease resistance will fall. This is especially true in connection with our lesser grown flowering plants and many of these lend themselves to the limited space of the home gardener.

¹⁷ Jones, L. R. Securing Disease Resistant Plants. How Important Is It? Whose Job Is It? *Science* 63:341-345. 1926.

OBSERVATIONS CONCERNING CLOVER DISEASES.¹

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Red clover has long occupied an important place in the world's agriculture. Of late years, the growing of clover has met increasing difficulties in some sections of the United States. While this is apparently due to a number of different causes,² disease is one of the important factors. The following observations concerning clover diseases were made in the vicinity of Lafayette, Indiana, during the period 1920-1927 while studying the rusts and mildew of clovers.

Anthracnose. This is probably one of the most important³ of the clover diseases in the United States. *Gleospodium caulivorum* and *Colletotrichum trifolii* both produce the condition known as anthracnose. Pieters and Monteith (*l.c.* 3) state that the *Colletotrichum* is the most prevalent in the southern part of the clover belt while *Gleospodium* is the most important northward. Monteith⁴ has found that the former is favored by high temperatures while the latter develops at lower temperatures, in keeping with their distribution. Both of these fungi have been found at Lafayette. In 1926, *Gleospodium* was the most prevalent, while this season (1927) *Colletotrichum* is very abundant.

The symptoms produced by both pathogens are very similar and consequently the two are not often distinguished. In the late spring and early summer, the disease is usually first noted as small dark lesions on the stems, petioles, peduncles, etc. The girdling of these causes a wilting and results in a bending of the petioles, etc., in a characteristic manner (Fig. 1). This may result in considerable defoliation even in the first cutting. When anthracnose is severe, especially during late summer and autumn, the tops are completely killed and the crown invaded and rotted. The root oftentimes remains in good condition for some time. Many plants which are not killed in the fall enter the winter in a weakened condition and die before spring so that good stands of clover may show only scattered plants in the spring.

In June, 1926, there was a moderate amount of anthracnose in the variety plots due to *Gleospodium*. French (38,631), Italian (2,424) and

¹ Contribution from the Department of Botany, Purdue University Agricultural Experiment Station.

² Pieters, A. J. Clover Failure. U. S. Dept. Agr. Farmer's Bul. 1365. 1924.

³ Pieters, A. J. and Monteith, J. Anthracnose as a Cause of Red Clover Failure in the Southern Part of the Red Clover Belt. U. S. Dept. Agr. Farmer's Bul. 1510. 1926.

⁴ Monteith, J. *Colletotrichum trifolii* and *Gleospodium caulivorum* on Clover (Abstract). Phytopath. 16:71. 1926.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

Altaswede were moderately infected while Indiana, Oregon (2,474) several French, Hungarian, Roumanian and Polish strains showed slight infection. A Chilean strain and most of the North American strains showed only a trace of infection.

In the autumn of 1927 considerable infection from *Colletotrichum* developed in the variety plots and by November several of the strains showed considerable crown infection and dead plants. The most severely infected were both North American strains, Oregon (14,266) and Idaho (14,120). Several Idaho, a Michigan, Wisconsin, Utah, Indiana, German and Italian strain were moderately infected. A number of French, a German, Hungarian, Polish, Russian, Roumanian, Chilean, Idaho, Colorado, Indiana, Ohio, Michigan and Tennessee strain showed a slight



Fig. 1--Anthracnose of red clover. The branch to the left showing characteristic bent leaflets and peduncle. The two plants to the right showing dead tops and rotted crown with the tap roots still in good condition.

amount of infection. Infection was not, however, uniformly distributed.

Monteith⁵ states that clover from seed raised in southern Europe is more susceptible to injury by anthracnose (*Colletotrichum trifolii* and *Gleosporium caulivorum*) than clover from North American seed. Pieters⁶ states that *Colletotrichum* was most severe at Washington, D. C., on plots from Italian and German seed. Bohemian, English, French, Polish, Oregon, Idaho and Minnesota strains were heavily infected. Chilean showed somewhat less injury. The Tennessee resistant strain and a strain from southwestern Ohio showed approximately no injury. Hesler,⁷ under conditions of moderate infection, found Roumanian, Chilean and Wisconsin strains moderately infected and Italian, French, Hungarian

⁵ Monteith, J. Relative Susceptibility of Red Clover to Anthracnose. (Abstract.) *Phytopath.* 14:62-63. 1921.

⁶ Pieters, A. J. Symposium—The Forage Problem. *Jour. Amer. Soc. Agron.* 16:153-238. 1924.

⁷ Hesler, L. R. Relative Susceptibility of Red Clover at Wooster, Ohio. *Plant Disease Reporter* 9:92-93. 1925.

and a number of North American strains slightly infected in Ohio. Adams⁸ states that a French strain showed abundant infection, while Italian, Minnesota and Oregon were moderately infected and English, Roumanian, Chilean, Ohio and Michigan showed slight infection by *Gleospodium* in Delaware.

That clover can be developed resistant to *Colletotrichum* has been demonstrated by Bain and Essary.⁹ It is not certain whether this strain will show sufficient resistance and adaptability in the northern part of the clover belt. However, their results indicate that resistant selections can be developed from adapted North American strains.

Powdery Mildew. *Erysiphe polygoni* first attracted attention in this country in 1922. Since that time it has been more or less prevalent in Indiana and is apparently established as one of the widespread diseases of red clover. The alarm with which its appearance was greeted has decreased since it has not resulted in marked damage. It covers the leaves with a dense white mat of mycelium and spores. Mildew probably greatly reduces the photosynthesis of the leaves and results in their premature death. This not only causes a loss of a valuable portion of the hay but tends to weaken the plant and may in the case of young seedlings reduce the chances of overwintering.

As has been previously noted¹⁰ resistant individuals are more or less prevalent in all strains of red clover. They occur in a greater proportion in those strains of European origin and oftentimes North American strains can be distinguished from European by their more generally mildewed appearance. The following notes illustrate this difference.

Relative Susceptibility in 1923

<i>Severe</i>	<i>Moderate</i>	<i>Slight</i>
Oregon 2148	Chilean 2055	Chilean 2217
Idaho 2220	Chilean 2203	Chilean 2142
N. Dakota 1809	Australian 2156	English 2253
S. Dakota 2019	English 43592	Polish 54905
Ohio 2020	N. German 2218	Bohemian 2121
Ohio 2135	French 55502	Hungarian 2219
Tenn. 2138	Italian 54492	Riga 55002
Canadian 2301		Hamburg 2214
		French 2213, 54456, 54493,
		2202, 56182
		Italian 54779, 1819, 2212

⁸ Adams, J. T. Relative Susceptibility of Red Clover Strains to Disease as Observed in Delaware, 1925. Plant Disease Reporter Supp. 48:368. 1926.

⁹ Bain, S. M. and Essary, S. H. Selection for Disease Resistant Clover. Bull. Tenn. Sta. 75, 10 p. 1906.

¹⁰ Mains, E. B. Differences in Susceptibility of Clover to Powdery Mildew. Proc. Ind. Acad. Sci. 1922. 307-313. 1923.

Relative Susceptibility in 1924

<i>Severe</i>	<i>Moderate</i>	<i>Slight</i>
Oregon 2396	Chilean 2394	Altaswede
2397G	Hungarian 56441	Chilean 2403, 2217
2148	Bohemian 2307	N. Zealand 56795
Idaho 2407	Swiss 56896	English 2399E, 2399J
Minn. 2398	Italian 56880	German 2399L
Mich. 2399A		French 2399H, 2401
Tenn. 2138		Italian 2429, 2397
Canadian 2409		

Relative Susceptibility in 1927

<i>Severe</i>	<i>Moderate</i>	<i>Slight</i>
Wis. 14126	Oregon 14266	Italian 2688
Minn. 14116	Idaho (Several)	French 2509, 2584, 2683,
Colorado	Utah	2687, 66127
Mich. 14118	S. Ind.	German 2665, 2666
N. Indiana		Hungarian 2667
Ohio 14121		Roumanian 2661
Tenn. 14026		Russian 67990
		Polish 65965
		Chilean 2658

This difference in the relative susceptibility of North American and European strains has been noted by a number of different investigators in various parts of the country. Apparently all of the strains contain resistant plants so that it should be possible to breed a strain highly resistant to mildew. This would be more difficult than for anthracnose since the mildew susceptible plants are not eliminated by the disease.



Fig. 2—Powdery mildew of red clover. The leaves to the right from a plot dusted with sulphur and practically free from mildew. Those to the left from the undusted check and heavily mildewed.

Sulphur has long been known as a fungicide for powdery mildews. During the summer of 1927, heavily mildewed plots of red clover were given two dustings with finely ground sulphur. While mildew continued to develop on the undusted checks it was practically eliminated from the dusted plots (Fig. 2). If control of the disease can be shown to result in a great enough saving, methods of dusting with sulphur will probably be developed which will control the disease.



Fig. 3—Bacterial leaf spot. To the left branch showing infected leaves. To the right an infected leaflet enlarged.

Bacterial leaf spot. This disease is caused by *Bacterium trifoliorum*.¹¹ In the vicinity of Lafayette it was first noted causing heavy infection of red clover in the spring of 1925. It develops largely during the spring months. It first appears as small water soaked spots which darken as they increase in size. The bacterial exudate is oftentimes so abundant that it gives a dark varnished appearance to the infected portions (Fig. 3). As the disease progresses the infected areas dry

¹¹ Jones, L. R., Williamson, M. M., Wolf, F. A. and McCulloch, Lucia. Bacterial Leafspot of Clovers. Jour. Agr. Res. 25:471-490. 1923.

up and break away giving a ragged appearance to the leaves. In cases of heavy infection considerable defoliation may result. Its development is apparently favored by the low temperatures of the spring months and its principal damage in the vicinity of Lafayette has been confined to the first cutting.

In 1925 it was specially severe on Roumanian 2399, Swiss 56896 and Indiana strains. Moderate infection was noted on Italian, French, Hungarian, Bohemian, Latvian, German, English, Chilean, Idaho, Michigan, Indiana and Canadian strains. Certain Italian, New Zealand, Chilean, Oregon, Minnesota, Indiana and Canadian strains showed slight infection while only a trace was noted on Finnish (56870) and a strain of Canadian alsike was free from infection. The Indiana check plots showed a considerable variation in the amount of infection so it is questionable to what extent these notes represent differences in relative susceptibility.

In 1926 the bacterial leaf spot was again severe in the variety plots and the foreign strains as a group were more heavily infected than the North American; Italian (2424, 2429), French (2414, 58472), Hungarian (2413, 2415, 59300), Roumanian (2423), Polish (58857), Pomeranian (2447), English (61333, 61332) and Chilean being severely infected; French (58631, 58632, 59290), Central Europe (2426), Michigan (2501) and Indiana being moderately infected; Michigan (2477) and Canadian (2404, 2409) slightly infected and Oregon (2474), Idaho (2407), Minnesota (2476), Wisconsin (2410), Tennessee D. R. (2469) Ohio (2471) and Altaswede showing only a trace of infection.



Fig. 4—*Macrosporium* leaf spot of red clover. A moderately infected leaf at the left and a heavily infected leaf to the right.

Macrosporium leaf spot. The *Macrosporium* leaf spot of clover is due to *Macrosporium sarcinaeforme*. It causes brown spots on the leaf which are characterized by alternate concentric rings of light and dark color (Fig. 4). In cases of heavy infection, these spots coalesce and the entire leaf may be killed. At Lafayette it has been most abundant in late summer and fall. In August, 1923, certain strains of Italian, French, Chilean clovers showed moderate infection while other strains

from the same origin as well as North European and North American showed slight infection. In the fall of 1927 it was specially abundant. All plots were more or less infected. Italian (2688), Russian (67990), Polish (65965), Roumanian (2661), German (2666), Chilean (2658), Minnesota (14116) and Tennessee (14026) showing somewhat less infection than other French, German, Hungarian and North American strains. Adams (*l.c.* 8) noted but little difference between foreign and North American clovers in the amount of this leaf spot. Krakover¹² has noted uninfected plants of red clover in the midst of badly diseased plants and considers that the control of this disease will depend upon selection and breeding of resistant strains.

Rust. The rust of red clover, *Uromyces fallens* (*U. Trifolii* of some authors) is characterized by brown powdery pustules on the leaves (Fig. 5). When it is severe, it causes premature death of the leaves.



Fig. 5—Rust of red clover. The two leaves to the left from susceptible plants. The leaf to the right from a resistant plant.

This disease was severe at Lafayette in the autumn of 1920. Plots of Indiana, North Dakota (1809), South Dakota (2019) and Ohio strains were heavily rusted while the Italian strains (1819, 2006) showed only a slight amount of rust. In the autumn of 1921 several different strains of red clover were inoculated with the rust in the field. The plants were spaced and counts were made of the severely, moderately and slightly rusted plants as follows:

		Rusted		
		Severely	Moderately	Slightly
South Dakota	2019.....	20	10	14
North Dakota	1809.....	1	1	7
Ohio	2020.....	12	19	12
Chilean	2055.....		7	10
French	.....		3	41
Italian	1819.....	1		9

A more extensive test was made in the greenhouse during the winter of 1922-1923. Out of 151 plants of three North American strains, 10

¹² Krakover, L. J. The Leaf-Spot Disease of Red Clover Caused by *Macrosporium sarcinaeforme*. Mich Acad. Sci. 19 Rept. 275-328. 1917.

were classed as resistant or 6.6 per cent. Of 125 plants of four Chilean strains, 25 were classed as resistant or 20.0 per cent. Of 314 plants of four eastern European strains, 59 were classed as resistant or 18.7 per cent. Out of 141 plants of four French strains, 38 were classed as resistant or 26.9 per cent. Of 208 plants of three Italian strains, 41 were classed as resistant or 19.7 per cent. All of the plants tested for rust reaction had previously been selected for resistance to powdery mildew (*l.c.* 10) so that the rust resistant selections were resistant to mildew as well. The foreign clover strains tested, therefore, contained a greater proportion of both mildew and rust resistant individuals than the North American strains.

Only a trace of rust was noted in the field in 1922 and 1923. Although a careful search was made for red clover rust in 1924, 1925, and 1926 no trace of the rust was found. In late October, 1927, it was again noted slightly infecting occasional plants which showed heavy infection by the middle of November. The rust of red clover apparently is usually of minor importance in the vicinity of Lafayette, Indiana, and this is probably true for the state as a whole although it may occasionally become severe locally.

The rust of alsike clover has been noted more frequently although it usually is found on scattered plants. In August, 1927, a number of plants of alsike were showing infection and by the first of October several plots of alsike were heavily rusted and considerably defoliated. This rust is apparently more prevalent than the red clover rust in Indiana. The rust of white clover has been occasionally received from different parts of the state but it has been noted in the vicinity of Lafayette only during the fall of 1927, when a few infected plants were found.

The rusts of red, alsike and white clovers are physiologically distinct and do not pass from one to the other. There are also some differences in morphology. Some investigators^{13 14} therefore, consider these distinct species, that on white clover *Uromyces trifolii-repentis* and that on alsike, *U. trifolii-hybridi*; that on red clover, *U. fallens* or *U. trifolii*.

Mosaic. Attention was first attracted to this disease in connection with some plants of red clover which had been brought into the greenhouse from the field. Not only were plants of red clover, *Trifolium pratense*, severely infected but *T. arvense*, *T. subterraneanum*, *T. incarnatum* and *T. resupinatum* showed mosaic, the last two being severely infected. The diseased plants showed mottling and contortion of the leaflets typical of mosaic diseases. (Fig. 6.) Various degrees of chlorosis were produced. In some plants only a few leaves showed a slight effect, while in others all the leaves were infected, showing pronounced chlorosis and necrosis along the veins. In severe cases the leaves died rapidly, followed finally by the death of the entire plant.

In 1925 mosaic was noted as specially prevalent in plots of Indiana,

¹³ Kobel, T. Zur Biologie der Trifolien-bewohnenden Uromycesarten. Centralbl. Bakt. 52:215-235. 1920.

¹⁴ Davis, W. H. Summary of Investigations on Clover Rusts, Mycologia 16:203-219. 1924.

Idaho and Minnesota strains. In 1926 the disease was abundant in plots of Indiana, Wisconsin, Canadian, Central European, English and French strains. In the autumn of 1927, it was especially noticeable in an Oregon strain.

Under the usual field conditions, it is difficult to determine the prevalence of this disease on account of the intermingling of healthy and diseased plants. In the autumn of 1927, however, mosaic was noted in a plot of spaced red clover planted by Prof. G. H. Cutler of the Agronomy Department. An examination of these plants showed that



Fig. 6—Leaves of red clover infected with mosaic showing chlorotic streaking and contortion.

out of a total of 390 plants, 24 showed severe infection, 34 moderate and 65 slight infection. In this planting, therefore, 31.5 per cent of the plants were infected with mosaic. The severely infected plants were in very poor condition, evidently dying. Orton¹⁵ has reported a 50 per cent infection on crimson clover in Pennsylvania. Elliot¹⁶ states that 75 per cent of the plants of red clover on the campus of the University of Arkansas showed mosaic in 1919. It is probable that mosaic is a much more important disease of clover than has been assumed.

Elliot found that red clover mosaic could be transmitted to sweet clover, *Melilotus alba*, burr clover, *Medicago arabica*, and horse bean, *Vicia faba*. Dickson¹⁷ found that infection took place between *Trifolium pratense*, *T. hybridum*, *T. repens*, *T. incarnatum*, *Medicago lupulina*, and *M. sativa* but not to *M. alba*. He also found that mosaic was seed carried. Seed from fields having a large percentage of mosaic plants should, therefore, be avoided.

Nematodes. A number of plants of red clover transplanted into the greenhouse in the fall of 1923 showed stunting and an examination of the roots resulted in finding the characteristic knotlike swellings produced by nematodes. This trouble has, however, never been noted in

¹⁵ Orton, C. R. Plant Disease Survey Suppl. 15, p. 171. 1921.

¹⁶ Elliott, J. A. A Mosaic of Sweet and Red Clovers. *Phytopath.* 11:146-148. 1921.

¹⁷ Dickson, B. T. Studies concerning Mosaic Diseases. *Macdonald College Tech. Bul.* 2:125 p. 1922.

the field in Indiana. It apparently is serious under field conditions only in the northwest.

Cercospora Spot. A cercospora leaf spot was noted moderately infecting alsike clover in the vicinity of Lafayette in 1923.

Sooty Spot. The sooty spot of white clover, *Phyllachora trifolii* (*Polythrincium trifolii*) has been noted every year in the vicinity of Lafayette. It is occasionally severe in small areas, causing considerable defoliation.

Root and Crown Rots. Several different root and crown rots have been noted with various fungi associated, especially species of *Fusarium*. In many cases these are probably secondary following anthracnose, mosaic, etc. In the spring of 1926 a crown rot was especially prevalent in Italian and French plots apparently due to a *Fusarium*. According to the investigations of Fergus and Valleau¹⁸ a number of species of *Fusarium* are responsible for clover root rots especially when favored by low soil productivity.

The control of clover diseases in most cases presents difficult problems. Apparently selection and breeding for resistance offers the most promise. While foreign clover strains show much greater resistance to such diseases as mildew and rust they are apparently for the most part more susceptible to anthracnose and are not adapted to most sections of the United States. Resistance to both mildew and rust occurs in North American strains and from these it should be possible to develop lines combining resistance to a number of diseases.

¹⁸ Fergus, E. N. and Valleau, W. D. A Study of Clover Failure in Kentucky. Agr. Exp. Sta. Bul. 269. 210 p. 1926.

INDIANA FUNGI—X.

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The fungi discussed in the present paper are, for the most part, those collected in 1926 and 1927, and all have been obtained within our state. We are now including a very limited number obtained from our local markets, since a record of their occurrence may be of future value, as our local flora has been and will continue to be enlarged by the escaping of many such species.

It has been interesting to note the appearance, this fall, of some early spring fungi as *Sarcoscypha coccinea*. The conditions which have brought about an unusual amount of fall blooming of spring flowers and shrubs, have affected some fungi in a similar manner.

The present paper, like all the former of this series, is entirely independent of any other published lists of Indiana fungi. Our plan is to revise or enlarge descriptions and in many cases, to redescribe rather than to present a long list or to seek new species.

For the sake of brevity, we have observed the following: When the county is omitted, it is Monroe; when the name of the collector is not given, it is that of the writer; the host is living, unless otherwise stated; the locality within the county is mentioned only when it is thought to be of considerable importance.

Since our primary interest concerns the so-called Imperfect group, comments are confined chiefly to those fungi.

PHYCOMYCETES.

Bremia Lactucae E. Regel. On leaves of *Sonchus oleraceus* L., Campus, May 25, 1927. I. U. Herbarium No. 4747.

Peronospora effusa Rabenh. On leaves of *Spinacea oleracea* Mill. From local grocery. Very common. Possibly brought in from outside the state. Jan. 4, 1926.

BASIDIOMYCETES.

USTILAGINALES.

Tilletia corona Scrib. In ovaries of *Homalocenchrus oryzoides* (L.) Poll. Collected one mile north of Bloomington, October 23, 1926, by P. Weatherwax. 4162.

UREDINALES.

Aecidium hydnoides Berk. & Curt. On leaves of *Dirca palustris* L., Turkey Run State Park, Parke County, June 26, 1926. Very common in ravines. 4138.

Coleosporium Vernoniae B. & C. *Vernonia noveboracensis* Willd.,
Edinburg, Aug. 27, 1925. Stacy Hawkins. 4108. Common
in Monroe County.

Dicaeoma Fraxini (Schw.) Arth. [*Puccinia fraxinata* (Lk.) Arth.]
On leaves of *Fraxinus viridis* Michx., Clay County, Aug. 1, 1927.
Otho Shaw. 4801.

CLAVARIACEAE.

Clavaria amethystina Bull. "Base of limestone beech slope about
five miles south of Milltown, Crawford County, June 17, 1927.
C. C. Deam. No. 44583." 4829.

POLYPORACEAE.

Fomes igniarius L. On body of living *Juglans nigra* L., some ten
feet from the ground, Matlock's Woods, 1917. 4164.

Polyporus cuticularis Bull [*Innotus perplexus* (Pk.) Murr.] On
Fagus grandifolia Ehrh., near the campus, autumn of 1926.
Hugh Ramsey. Odor very strong; spores bright brown. These
specimens were filled with budding cells of a species of yeast.
4165.

AGARICACEAE.

Ananita abrupta Pk. Campus, July 15, 1925. 4074.

Panus rudis Fr. On dead area of the body of live *Sorbus Aucuparia*
L., campus, June and July, 1925. The pilei extended from
the ground to a distance of six feet up the tree. They ap-
peared again in both 1926 and 1927, apparently producing an
ever increasing canker-like area. 4072.

GASTEROMYCETES.

Geaster hygrometricus Pers. On ground, Nov. 27, 1926. Robinson.
4166.

Geaster minimus Schw. Moore's Creek, Oct., 1907. W. L. Wood-
burn. 2348.

ASCOMYCETES.

Claviceps purpurea (Fr.) Tul. On *Dactylis glomerata* L., near
state park, Steuben County, Aug. 10, 1927. Weatherwax. 4809.
Didymellina Iridis (Desm.) v. Hohn. [See *Heterosporium gracile*
(Wallr.) Sacc.] 4754.

Diplocarpon Rosae Wolf. [See *Actinonema Rosae* (Lib.) Fr.] 4200.

Epichloe typhina (Pers.) Tul. On *Sphenopholis pallens* (Spreng.)
Scrib., Brown County, July 18, 1926. Weatherwax. 4141.

Erysiphe cichoracearum D. C. On leaves of *Zinnia elegans* Jacq.,
Oct. 30, 1927. Terzo Amidei. 4825.

Erysiphe Polygoni D. C. On leaves of *Ranunculus abortivus* L.,
(young plants). Campus, Oct. 15, 1927. 4824.

Erysiphe Polygoni D. C. On *Trifolium pratense* L., June and July,
1927. 3922. Also occurring to a less degree on *T. hybridum* L.
and *T. repens* L. The writer first noted the severity of this

disease in Ohio in 1921. In 1922 it was common and destructive over much of Indiana. It developed rapidly early in the season, and began to cause comment about June 1. We find only the conidial stage. 3922.

Exoascus deformans (Berk.) Fckl. On leaves and ends of growing twigs of *Prunus Persica* Batsch., Johnson County, about May 1, 1927. This disease was unusually severe on unsprayed trees in 1927, causing almost complete defoliation in many cases. 4740.

Gibberella Saubinetii (Mont.) Sacc. On sheaths of *Zea mays* L., campus, Oct. 15, 1926. 4155.

Gnomonia veneta (Sacc. & Speg.) Kleb. [See *Gloeosporium nervisequum* (Fckl.) Sacc.] 4143.

Hypoxyylon atropunctatum Fr. On wood, Clay County, July 17, 1927. Shaw. 4771.

Microsphaera Alni (Wallr.) Wint. On leaflets of *Gleditsia triacanthos* L., in 1915. 4192.

Microsphaera Alni Vaccinii (Schw.) Salm. On leaves of *Catalpa Bungei* C. A. May, Oct., 1927. 4816.

Nummularia Bulliardii Tul. On wood, Clay County, July 17, 1927. Shaw. 4772.

Phyllachora graminis (Pers.) Fckl. On *Muehlenbergia Schreberi* J. F. Gmel., campus, Oct. 25, 1927. Amidei. 4819.

Pseudopeziza medicaginis (Lib.) Sacc. On leaves of *Medicago sativa* L., Clear Creek, June 1927. Lois Stump. 4762. This leaf-spot of alfalfa was unusually severe in the year 1927, causing early leaf defoliation. Crops were cut early to save the leaves. 4762.

Sarcoscypha coccinea (Jacq.) Fr. On buried stick, Nov. 13, 1927. Stump. 4835.

Sphaerotheca humuli (D. C.) Burr., var. *Fuliginea* Schlecht. On leaves and stems of *Sonchus asper* (L.) All., injuring the host late in the season. Our material has larger perithecia than is given by Salmon in his Monograph of the Erysiphaceae. They are larger, averaging about 100 microns, while other characters agree with the regular species, *S. humuli*. 4822. On leaves of *Prunella vulgaris* L., Oct. 30, 1927. Amidei. 4826.

Sphaerotheca pannosa (Wallr.) Lev. On leaves of cultivated rose, Jasper, Sept. 1, 1926. Wilson. 4207.

Uncinula circinata Cke. & Pk. Very common and abundant on living leaves of young *Acer saccharum* Marsh., campus, Oct. 15, 1927. Amidei. 4820.

Uncinula flexuosa Pk. On leaves of *Aesculus glabra* Willd., late in summer, 1926. 4189.

Uncinula necator (Schw.) Burr. On leaves of *Vitis cordifolia* Michx., University dam, Oct., 1927. Amidei. 4834. Same on *Ampelopsis quinquefolia* Michx., Biology Building, Oct. 19, 1927. Amidei. 4818. Both lots of material are very fine.

Xylaria polymorpha (Pers.) Grev. Clay County, July 17, 1927. Shaw. 4770.

FUNGI IMPERFECTI.

SPHAEROPSIDALES.

- Actinonema Rosae* (Lib.) Fr. (*Diplocarpon Rosae* Wolf.) On cultivated rose leaves, Clark County, 1926. 4200. The black spot of rose leaves is very common late in the season each year.
- Ascochyta althaeina* Sacc. & Bizz. On leaves of *Althaea rosea* Cav., six miles west of Bloomington, July 1, 1925. 4097. This species was associated with *Cercospora Kellermani* Bubak. (A thorough study of this species is being made.)
- Ascochyta Aquilegiae* (Roum. & Pat.) Sacc. On leaves of *Aquilegia canadensis* L., in D. M. Mottier's yard, July 1, 1927. 4760. So far as the writer is aware, this fungus has not heretofore been reported from America. Our description follows: Spots circular or oval, $\frac{1}{2}$ to $1\frac{1}{2}$ cm. in diameter, or sometimes spreading over a large area of the leaf, especially at its edge, dark brown, and bounded by yellow concentric, elevated rings, gray beneath; pycnidia large, 125 to 150 microns in diameter, located near the center of the spots, their pores being 25 to 30 microns across and ragged; spores hyaline, oblong, elliptical, straight or curved, mostly with two small guttulae, becoming two-celled and four-guttulate, and a few two-septate. The two-celled ones are often constricted at the septum or the cells may be of unequal size. The descriptions in Saccardo, vol. III, p. 396, and vol. XXII, p. 1013, taken together, correspond fairly well with our plants.
- Ascochyta Plantaginis* Sacc. & Speg. On leaves of *Plantago Rugelii* Dene., July 25, 1920. 4105. Also collected by G. Blaydes, June 17, 1924. 4013. It agrees well with the description except that most spores have two guttulae in each cell. Number 4105 is associated with *Septoria inconspicua* B. & C. and a *Diplodia*.
- Ascochyta Rhei* E. & E. On leaves of *Rheum Rhaponticum* L., Clay County, Aug. 1, 1927. Shaw. 4806. The pycnidia measure 70 to 150 microns in diameter.
- Discosia artocreas* (Tode.) Fr. On spots on leaves of *Sassafras variifolium* (Salisb.) Ktze., Sept. 1, 1926. Wilson. Du Bois County. 4205.
- Dothiorella Asiminae* E. & E. On dead twigs of *Asimina triloba* Dunal., campus, Oct. 15, 1927. Our material has pycnidia $\frac{1}{4}$ to 1 mm. in diameter and spores 2 by 7 microns and mostly allantoid.
- Entomosporium Thuemenii* (Cke.) Sacc. On leaves of *Crataegus oxyacanthae* L., campus, Thomas. 4115.
- Phleospora maculans* (Bereng.) Allesch. [*Fusarium maculans* Bereng. *Phleospora Mori* (Lev.) Sacc. *Septoria Mori* Lev. *Fusisporium cingulatum* Mont. *Fusisporium Mori* Mont. *Septigloeum Mori* (Lev.) Brios & Cavar. *Cheilaria Mori* Deem.] On living leaves of *Morus rubra* L., Griffey Creek, July 2, 1927. G. A. Loughridge. 4764. Spores are 3 to 5 by 25 to 80 microns, hyaline, variously curved or bent, guttulate, and mostly three-

septate. (The septa are difficult to observe on account of the guttulae.)

Phoma uvicola B. & C. (See *Phyllosticta Labruscae* Thuem.) Common on cultivated grape berries every year.

Phyllosticta ambrosioides Thuem. On leaves of *Chenopodium ambrosioides* var. *anthelminticum* (L.) Gray., Clay County, Aug. 1, 1927. Shaw. 4805. Agrees most excellently, except that our spores are $1\frac{1}{2}$ by 4 to 7. They are given as $1\frac{1}{2}$ by 4 to 5 microns.

Phyllosticta Asiminae Ell. & Kell. On leaves of *Asimina triloba* Dunal., campus, Oct. 14, 1927. 4813. Pycnidia abundant over the entire spot, 75 to 125 microns with definite spores about 12 microns in diameter. Spores granular, numerous. This species is very common throughout the range of its host in the state. The leaves are often beset with spots of various sizes, many of which coalesce and often destroy most of the leaf. The spots fall away particularly during rainy weather.

Phyllosticta Labruscae Thuem. [*Guignardia Bidwellii* (Ell.) Viala & Ravaz. See also *Phoma uvicola* B. & C.] On living leaves of *Cissus Ampelopsidis* Pers. (*Ampelopsis quinquefolia* Michx.), campus, June 27, 1927. Stump. 4761. Common every year.

Phyllosticta minima (B. & C.) E. & E. On leaves of *Acer saccharum* Marsh., in woods, Scott County. Hawkins, August 29, 1925. 4107.

Phyllosticta minutissima E. & E. On leaves of *Acer Negundo* L., campus, Oct. 12, 1926. 4172. Agrees well except spots are as much as 1 cm. or more in size.

Phyllosticta phomiformis Sacc. On leaves of *Quercus* sp., campus, Aug. 4, 1926. Wilson. 4150.

Phyllosticta Platani Sacc. & Speg. On leaves of *Platanus orientalis* L., campus, Oct. 22, 1926. H. L. Eaton. 4169.

Phyllosticta verbascicola Ell. & Kell. On leaves of *Verbascum Thapsus* L., Clear Creek, July 18, 1927. Stump. 4769. This material is exactly typical of original description.

Septoria Apii Rostr. On leaflets and leaf stalks of *Apium graveolens* L. Common in market, October and November, 1924, no. 4125. Oct. 30, 1927, 4823.

Septoria inconspicua B. & C. On leaves of *Plantago Rugelii* Dene., July 25, 1920. 4103. Associated with *Ascochyta Plantaginis* Sacc., *Ramularia Plantaginis* Pk., and a *Diplodia*. Spots chiefly along edges of leaf, indefinite; pycnidia about 50 to 75 microns with pore definite and 12 to 15 in diameter; spores very slender, $\frac{1}{2}$ to 1 by 15 to 25 microns, straight or curved, hyaline.

Septoria Nolitantere Thuem. On leaves of *Impatiens pallida* Nutt., Griffey Creek, July 20, 1927. 4787. Corresponds well with published descriptions. Our material shows pycnidia 50 to 100 microns in diam., most of them being about 50. The spores are $1\frac{1}{2}$ by 15 to 25, and often one or sometimes several septate. So far as we are aware, this species has not heretofore been reported from the United States.

Septoria Oenotherae West. On leaves of *Oenothera biennis* L., Aug. 7, 1915. 3633. Varies in having spores $1\frac{1}{2}$ to 2 by 25 to 82 microns.

MELANCONIALES.

Gloeosporium affine Ell. & Kell. On leaves of *Sassafras variifolium* (Salisb.) Kitz., Griffey Creek, July 2, 1927. Loughridge. 4767. Common.

Gloeosporium Coryli (Desm.) Sacc. On leaves of *Corylus americana* Walt., campus, Oct., 1921, 4109; Oct. 12, 1923, 4001; July 20, 1926, 4140. Pycnidium covered by membranaceous tissue, flat, circular or oval, 50 to 100 microns, opening by a slit; spores mostly oblong but occasionally narrowed at one end, 5 to $7\frac{1}{2}$ by 12 to 17 (average about 7 by 13.). [Syn. *Cheilaria Coryli* Desm. & Rob., *Labrella Coryli* (Desm. & Rob.) Sacc., *Phyllosticta corylina* Ell. & Mart.] This species has proved to be puzzling on account of the nature of the covering of the fruit body. The writer has hesitated to place it elsewhere than *Labrella Coruli* (Desm. & Rob.) Sacc., as this genus seems to have been erected to suit such fruiting forms.

Gloeosporium nervisequum (Fckl.) Sacc. [*Gnomonia veneta* (Sacc. & Speg.) Kleb.] On leaves and young twigs of *Platanus occidentalis* L., Parke County, June 26, 1926. 4143. Abundant on veins but not occurring to any extent on twigs in 1926. The disease of sycamore caused by this fungus had been increasing in severity for a number of years, some old trees finally succumbing from its effects; but in 1925, it was almost wholly absent, probably due to the very unusually dry weather at the time of spring infection. In both 1925 and 1926 its injurious effects were slight in Monroe County.

Gloeosporium Ribis (Lib.) Mont. & Desm. (*Pseudopeziza Ribis* Kleb.) On leaves of *Ribes Grossularia* L., garden, June 13, 1927. Stump. 4752. Severe this year.

HYPHOMYCETES.

Alternaria olivaceum (E. & E.) (*Macrosporium olivaceum* E. & E. Proc. Acad. Phil., 1894, p. 383.) On *Phyllosticta Asiminae* Ell. & Kell., which, in turn, is on *Asiminae triloba* Dunal. The conidiophores arise particularly from the pycnida of its host, very many coming through the pore in tufts. The conidiophores are 4 to 6 by a maximum of 100 microns. The spores are in chains, measure 7 to 15 by 20 to 37 microns, and are three to 5-septate, many being muriform. On account of its very close resemblance to *Macrosporium olivaceum* E. & E., we feel justified in placing it as *Alternaria olivaceum* (E. & E.). It was reported originally by Ellis and Everhart on *Sphaeropsis Asiminae* E. & E. which occurred on *Asimina triloba*. The spores hang together unusually well, remaining in chains in water mounts made from the leaves.

- Botrytis cinerea* Auct. On leaves and young growing canes of *Ribes odoratum* Wendl., July 12, 1926. 4142. Collected each year since 1918. It produces a disease known as "Die Back." [See Proc. Ind. Acad. Sci., vol. 36, 1926 (1927).]
- Cercospora beticola* Sacc. On leaves of *Beta vulgaris* L., Jay County, Sept. 2, 1926. Wilson. 4838.
- Cercospora mississippiensis* Tracy & Earle. On *Smilax lanceolata* L., shipped from the south, Dec. 15, 1925. Included here, as such material is usually cast out and might easily have become the source of infection of our native species, as *S. rotundifolia* L.
- Fusicladium dendriticum* (Wallr.) Fckl. [*Venturia inequalis* (Cke.) Wint.] On leaves of *Pyrus coronaria* L., field, Griffey Creek, July 20, 1927. 4800.
- Graphium Hamamelidis* Van Hook. Ind. Acad. Sci., vol. 35, p. 231, 1925 (1926). On living leaves of *Hamamelis virginiana* L., in Brown, Clark and Monroe counties; also in New York and Ohio. 3852. 4082.
- Heterosporium gracile* (Wallr.) Sacc. [*Didymellina Iridis* (Desm.) v. Hoehn.] On leaves of *Iris* varieties, June 10, 1927. Several collections made in Bloomington by Hudelson who also contributed material from Brown County. 4742. 4754. By far the worst in the observation of the writer, causing serious destruction of leaves.
- Ramularia lactea* (Desm.) Sacc. On small leaves of seedlings of *Viola sororia* Willd., campus, Oct. 15, 1927. 4821. Agrees except spots brown with olive to yellowish margins; spores 2 to 3 (occasionally 4) by 18 to 25 microns, sometimes hanging together in chains of a few. So far as is known to the writer, this species has not been previously reported from the United States. However a *Ramularia* sp. on a species of *Viola* reported from Washington state, may be this one. While our specimens do not agree fully with published descriptions, the variation of the species, together with the fact that they occurred on seedlings late in the season, may account for the difference shown by our fungus.

MYCELIA-STERILIA.

- Sclerotium Rolfsii* Sacc. On cultivated *Iris* in gardens, causing much destruction from rotting at the ground, July, 1926. 4153. Also on *Funkia ovata* Spreng., yard in Bloomington, Oct. 15, 1926. 4154. This caused all the leaves of the rosette to rot off at ground, the surface of the ground being covered with sclerotia.

STRUCTURE OF SOME CARBONIFEROUS PLANTS FROM ILLINOIS.

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In the few years since the discovery in America of those petrifications known as coal balls by Doctor Noé, of the University of Chicago, his students and others have described a number of American Coal Measure Plants based on structure from this type of material.

This paper deals in a preliminary way with some additional forms, not heretofore described from American material.

The petrifications which formed the material basis of this paper were collected, either by Doctor Noé or by the writer from the McLeansboro formation of the Coal Measures of Illinois.

The specimens described fall into three orders of vascular spore-bearing plants, the Lycopodiales, Equisetales and Filicales.

I. Lycopodiales: One of the common Coal Measure representatives of this order is *Lepidodendron*. Anatomically, two general types of steles are recognized, those in which a continuous ring of primary xylem encloses a central pith, and is in turn immediately enclosed by the cortex, and those in which the primary wood may or may not enclose a pith, but is surrounded by a definite zone of secondary wood, which often is of considerable thickness. Of the dozen or more British species known from structure, about half belong in each group. Our specimen of the first type has a relatively large and well preserved pith. The primary xylem forms a fairly narrow but continuous zone, with the protoxylem occurring as small groups of tracheids on the periphery of the woody zone. The tissue outside the xylem is not well preserved, and little is known of the structure of the cortex. The stem has a diameter of about 20 mm.

A decorticated stem approximately four inches long and an inch in diameter illustrates the second type of stem, in which the primary wood is surrounded by a zone of secondary wood. In this case the secondary wood formed a relatively thick zone, and the indications are that an unknown amount of wood was removed before petrification occurred.

The pith, while probably occurring in a branch of this size, is not preserved. The primary wood is continuous and of uniform character throughout part of the cylinder only, as part of the circumference is broken into units which give the appearance of individual bundles. The tracheids of the primary wood have the usual scalariform markings on all walls, and the protoxylem is easily recognized on the outer circumference of the primary wood.

The radially arranged cells of the secondary wood are slightly smaller than those of the primary. The pith rays are narrow and fre-

quently contain spiral elements. Occasionally a leaf trace is encountered passing out through the secondary wood.

Nothing can be told of the phloem and cortex of this particular specimen.

A common fossil in these petrifications is *Stigmaria*, the underground part of *Lepidodendron*, and also the underground part of *Sigillaria* and *Bothrodendron*, other coal measure members of the arborescent Lycopodiales. In transverse section it may be seen that there is a very small development of primary wood, which grades promptly into the secondary wood. The smallest tracheids, those with spiral markings constituting the protoxylem, contrary to the situation found in the stem of *Lepidodendron* and contrary to the situation most generally found in the living members of the Lycopodiales, are found next the pith, and consequently the entire development of the primary wood of *Stigmaria* was centrifugal.

Primary rays divide the woody stem into bundles. Traces to the so-called "rootlets" are frequently found traversing these primary rays, and in tangential section appear as tongues of wood, with the apex free in a cavity formed by the breaking down of the parenchyma tissue of the ray. The point of the rootlet trace, consisting of the spirally marked protoxylem cells, is directed toward the growing point of the *Stigmaria*.

The "rootlet" in transverse section consists of a small centrally placed stele and a wide cortex. The cortex has three distinct zones of tissue; the inner cortex, which is a narrow zone of parenchyma immediately surrounding the vascular elements; the middle cortex, generally not preserved, made up of very thin-walled cells, and the outer cortex, composed of compact heavy-walled cells.

The vascular strand as a rule has only the wood preserved, but occasionally all the tissues of the rootlet remain. The xylem in transverse section is somewhat triangular, with the protoxylem at one apex which is generally somewhat elongated. The phloem, when it can be identified, is more abundant on the side of the triangle opposite the protoxylem point, and while it may extend somewhat around the xylem, never encloses it. The phloem is difficult to identify as distinct from a possible pericycle and other parenchyma tissue.

Secondary xylem sometimes occurs in the form of a few radially arranged rows of tracheids on the side of the primary xylem opposite the protoxylem.

The endarch collateral bundle of *Stigmaria*, and the vascular arrangement of the "rootlet" in which the primary xylem and phloem are not radial but are on the same radius, seem to prohibit the consideration of *Stigmaria* and its appendages as true roots. Rather it would seem that *Stigmaria* is an underground stem and the *Stigmaria* "rootlets" are of the nature of modified foliar organs.

II. Equisetales: The foliage of Calamites, an arborescent Coal Measure member of the Equisetales was of two types; a narrow linear form, *Asterophyllites*, the anatomy of some species of which is well known due to several excellent investigations of leaves of this type found attached to Calamitean twigs, and a type of foliage known as

Annularia, which is broader than Asterophyllites, slightly united at the base into a sheath, and often spatulate in form. Annularia is not positively known based on structure.

Certain unattached foliar parts of Calamites have been described, but the possibility is always present that they represent not the foliage, but the sterile bracts of a Calamitean fructification. Numerous sections of such a foliar organ from the Illinois Petrifications show, however, such a close comparison not only as to dimensions of impressions of leaves of the Annularia type, but also as to the anatomical details of leaves of the Asterophyllites type, that it seems probable that the sections are those of a Calamitean leaf of the Annularia type.

III. Filicales: Though the systematic position of Psaronius is not at present determined without the possibility of change, it is generally accepted that it belongs in the Filicales. Free rootlets of Psaronius are common in many coal balls and in some instances have remarkable preservation, and are unusual in the small number of xylem arms in the stele of the rootlet, sometimes having as few as four, although commonly having five or six in this specimen. The cortex consists of a wide inner zone, composed of extremely lacunar tissue, bounded on the outer side by a narrow zone of sclerenchyma tissue, which in turn is again surrounded by parenchyma and the epidermis.

Those rootlets making up the "rootlet" zone, which immediately surrounds the stele of the stem, differ from the free rootlets in the absence of the outer parenchymatous zone, the sclerenchyma apparently being the limiting tissue except where the cells have elongated to form the filamentous interstitial tissue. The stelar anatomy of several species of Psaronius is well known; that of the specimen under discussion is not at present sufficiently investigated to offer at this time.

The Botryopteridaceae, or according to Bower, the Caenopteridaceae, is a group of true ferns which have not thus far proved abundant in American coal measure petrifications. Two genera are herein presented: Botryopteris, of the Botryopterideae, and Anachoropteris, of the Anachoropterideae.

Botryopteris was first made known by Renault, in his description of *B. forensis*. Several British species and at least one Belgian species have since been described. One of the interesting characteristics of Renault's *B. forensis* was the elongation of the three xylem arms of the bundle of the petiole in the form of the Greek letter ω . Our American specimen shows no contradiction to Renault's specimen in the matter of dimensions nor anatomy, with one exception. The hairs which clothe the stems and petioles of Botryopteris generally, had a peculiar arrangement in the case of *B. forensis*, in, that each cell of the hair had a ring of teeth at the distal end, giving the hair the appearance of a miniature equisetum. Excellent views of the hairs of our specimen failed to show any such arrangement. However, it is not considered that this difference is specific, in view of the constant similarity of all the other features.

The Anachoropterideae are known by the only representative, Anachoropteris, based on the description of petiole and fructification. The

stem is not known. The petiole, however, has a characteristic anatomical arrangement which is not easily confused with other genera.

The petiole bundle of *Anachoropteris* is concentric with the margins considerably revolute. Apparently the convex side of the bundle was turned toward the stem. The xylem encloses a mass of sclerenchyma which was continuous with the outer cortex. The inner cortex was not preserved.

The protoxylem is located on the convex side, slightly enclosed in the primary xylem. There appear to be four such groups. The pinnae traces are given off from the convex side and are connected with a protoxylem group.

A comparative study of the petiole of *Anachoropteris* and also the fructification identified by Kubart, would seem to show that there is not a close relationship between the *Anachoropterideae* and the other members of the *Botryopteridaceae*.

THE FERNS OF TURKEY RUN.

OTTO BEHRENS, JR., Anderson.

Turkey Run Park consists of about 900 acres of land situated in Parke County, about ten miles north of Rockville,—the county seat. The park is almost completely wooded. Over 200 acres are virgin woods and all the rest except a few areas are second growth timber. These areas, other than one cultivated field, are covered with undergrowth and weeds of many kinds.

Sugar Creek runs approximately east to west through Turkey Run and empties into the Wabash River about ten miles from Turkey Run. Canyons of sandstone formation, found on either side of Sugar Creek, were formed in the Mansfield Age of the Pennsylvania Era. There are five main canyons ranging from a few feet to 65 feet in depth, namely—Rocky Hollow, Bear Hollow and Boulder Canyon on the north side of the creek and Turkey Run Hollow and Newby Gulch on the south side.

In these canyons are exposed rock ledges and overhanging cliffs whose moist surfaces are well adapted for the growth of many species of ferns, lichens, mosses and liverworts. Back of the canyons are moist, shady woods rich in flowers and mosses and well suited to many of the deep wood ferns. These many favorable habitats suitable to various kinds of ferns make Turkey Run especially rich in different species and also in abundance of individuals.

Following is the list of ferns and their allies as found in Turkey Run State Park between June 20 and September 7, 1927.

1. Common maidenhair fern.—*Adiantum pedatum* var. *aleuticum* (L.) Rupr. The maidenhair is distributed throughout the park in the uplands. It is one of the most common of the ferns found in Turkey Run and ranges in size from about six to eighteen inches across, and from one to two feet in height.
2. Goldie's fern.—*Thelypteris Goldiana* (Hook) Nieuwl. One of the largest species of ferns of the park. Often the fronds are three feet in height. Although not common, it is frequently found in the park, especially in the rich woods back from trails 4, 8, 3, and 5.
3. Marginal shield fern.—*Thelypteris marginalis* (L.) Nieuwl. Throughout Turkey Run we may find this fern in the deep woods. It is one of the most common of the ferns of the park. It is especially abundant along Lover's Lane, trail 1 and on trail 7.
4. New York fern.—*Thelypteris noveboracensis* (L.) Nieuwl. This delicate fern in Turkey Run has been found on what is known as the Test Trail. It is situated on the top of the ledge of Rocky Hollow. Although not common, it is frequently found in rich woods and among second growth timber.

5. American spinulose shield fern.—*Thelypteris spinulosa* var. *americana* (Fisk) Weatherby. Common in rich woods of Turkey Run, often growing from two to two and one-half feet in height.
6. Ebony spleenwort.—*Asplenium platyneuron* (L.) Oakes. In only two places did we find this fern and in each place it was abundant. The first place was on the moist north exposed banks at the north-west part of trail 2 and the other place in the wet, rich woods east on trail 2 from the head of Newby Gulch.
7. Silvery spleenwort.—*Athyrium acrostichoides* (Sw.) Diels. Among the narrow-leaved spleenworts we found this fern to be frequent. It was found in situations like those of its relative, the narrow-leaved spleenwort, and is especially abundant on trail 8.
8. Narrow-leaved spleenwort.—*Athyrium angustifolium*. (Michx.) Milde. In shady ravines which were filled with rich soil and moisture this fern was found to abound. On September 1, before we closed our summer's work, we found a few of these ferns on which the spores were developing.
9. Upland lady-fern.—*Athyrium angustum* (Willd.) Prisl. Frequent though not common in most parts of the park.
10. Rattlesnake fern.—*Botrychium virginianum* (L.) Sw. This peculiar fern was found scattered throughout the park in places where the soil was very rich. On trail 8 near the coal mine this fern is locally most abundant although it may be found on nearly every trail in the park, where it is only rare to frequent.
11. Walking fern.—*Camptosorus rhizophyllus* (L.) Link. Although this very peculiar fern prefers limestone we found it to be quite common on the sandstone cliffs in the canyons. It is especially abundant in Rocky Hollow, and Turkey Run Hollow.
12. Bulblet bladder fern.—*Filix bulbifera* (L.) Beruk. The graceful fronds of this fern may be found in all of the canyons in Turkey Run. There we found them with the peculiar bulbs on them during the first half of the summer. It is especially common in Rocky Hollow and in Gypsy Gulch.
13. Fragile bladder fern.—*Filix Filix fragilis* (L.) Esten. Common in certain localities in the park, especially in damp places under the cliffs in the hollows. Found with the bulblet bladder fern in Rocky Hollow and Gypsy Gulch.
14. Sensitive fern.—*Onoclea sensibilis*. L. In some moist soil under the second growth of trees we may find this well-known fern. It is especially abundant on trail 8, being found in large patches with the long-beech, maidenhair, and cinnamon ferns.
15. Cinnamon fern.—*Osmunda cinnamomea* L. This fern is found in the more wet places among the sensitive fern. It was also found on the Test trail and ranged from about 18 to 30 inches in height. It fruits very early in the spring.
16. Broad beech fern.—*Thelypteris hexagonoptera*. (Michx.) Weatherby. This fern was rarely found among the long beech ferns. It was found in a similar habitat but is much rarer than the long beech fern.

17. Long beech fern.—*Thelypteris phegopteris* (L.) Slosson. Throughout the second growth of the park this fern was found to be frequent to common, especially back from trails 3, 5, 4, and 8.
18. Common polypody.—*Polypodium vulgare*. L. Abundant to common on rocks and cliffs in all the hollows of the park.
19. Christmas fern.—*Polystichum acrostichoides* (Michx.) Schott. This well-known fern is very abundant in Turkey Run where the soil at many places is very rich. It is common on practically every trail in the park.
20. Purple cliff brake.—*Pellaea atropurpurea* (L.) Link. This fern has been found and reported as rare to frequent by many observers prior to 1926. It was reported by Miss Caroline H. Swanson of Chicago University in 1925 on west overhanging cliffs in Turkey Run Hollow on trail 6, about 50 to 100 feet south of the mouth of Turkey Run Creek and along the north banks of Sugar Creek near the covered bridge. It was not found in 1927.

Charles Deam reports the maidenhair spleenwort, *Asplenium Trichomanes* L., from Parke County, but it was not found at Turkey Run during the summer of 1927.

The ferns in the above list are listed according to the check list used by G. H. Tilton in his "Check List on the Ferns of Northeastern America." The nomenclature used is the later one adopted and now used at the Gray Herbarium.

In the study of the ferns during the last summer both Mr. S. R. Esten of Pendleton and Mr. Fred Test of Lafayette helped in making the above list. The ferns of the above list have been checked and verified as to species by Dr. Flora Anderson of the Botany Department of Indiana University.

NEW YELLOWS RESISTANT VARIETIES OF CABBAGE IN INDIANA.

C. T. GREGORY, Purdue Agricultural Experiment Station.

The yellows resistant varieties of cabbage have proven to be a decided success in Indiana. In no case has the resistant quality broken down under our conditions. The chief difficulty has been, however, that nothing but mid-season to late varieties have been available. This year three early varieties, Marion Market, Allhead Select and Iacope, were tried. They proved to be quite successful both as to their resistance to yellows and to their market value.

The Marion Market is a selection made at Wisconsin from Copenhagen Market. The Allhead Select is another Wisconsin selection from the Allhead Early variety. Iacope was developed in Iowa from Copenhagen Market.

At Indianapolis these varieties were planted on yellows infested soil beside the variety Golden Acre. On August 8, these plots were visited. At that time what remained of the Golden Acre was being harvested and the Marion Market was just ready to be cut. About 50 per cent of the Golden Acre plants had been destroyed by the yellows. The Marion Market was 95 per cent resistant, but was about a week later in maturing. The Iacope was 90 per cent resistant and matured at about the same time as the Allhead Select.

At Evansville the reports were even more favorable. Marion Market was 98 per cent resistant, was first to mature the heads, of which 96 per cent were marketable. All Seasons, another resistant variety, was second in maturity. It was also 98 per cent resistant and produced 94 per cent of marketable heads. Allhead Select was third in maturing, was equally resistant and produced 94 per cent marketable cabbage. Iacope was fourth to head. It was a little less resistant, 95 per cent, but only 75 per cent of the heads were marketable.

In Lake County at Hammond, the Marion Market was 90 per cent resistant and in the Allhead Select 95 per cent of the plants were free from the disease. Under these conditions the Marion Market matured earlier than the Allhead Select but the grower reports that it was not as early at the common Copenhagen Market nor are the heads as solid and heavy. The Allhead Select pleased this gardener more since the heads were solid and large.

At Logansport the Marion Market was considered to be the best variety. It was 95 per cent resistant and produced a solid, medium-sized, round head. On the other hand, the Allhead Select, though just as resistant, produced large, flat heads that did not get solid. Both of these varieties head at the same time as the Glory of Enkhuisen or

what the gardeners term second early. All this cabbage was planted in disease-infested soil, as is proven by the fact that 40 per cent of the Glory of Enkhuisen was destroyed by the yellows.

It would appear from these reports that the Marion Market is most suitable for markets demanding a small, solid head of cabbage. For kraut purposes, the Allhead Select may be more suitable, since it is larger and looser. The Iacope variety, while it is sufficiently resistant, does not seem to have the quality demanded by the gardeners. It tends to large, flat heads and looseness of texture that is often undesirable in market varieties. It is apparent, too, that resistance seems to be linked with lateness, at least none of these varieties are as early as the parent type. However, this fact is not sufficient to condemn the varieties, since they do possess a remarkable resistance to the yellows and will produce large crops on badly infested soil.

For the late varieties, the Wisconsin All-Seasons, Wisconsin Succession, Wisconsin Hollander and the Indiana still retain their place in the lead. The Bugner variety developed at Chicago has not proven acceptable. Where it has been grown the plants are large, the leaves are coarse and too often it fails to produce a head, but still it is resistant.

CONTROLLING TOMATO LEAF MOLD IN GREENHOUSES IN INDIANA.

C. T. GREGORY, Purdue Agricultural Experiment Station.

One of the most serious diseases of tomatoes in greenhouses in Indiana is the tomato leaf mold (fig. 1). It is not universally present but where it does occur it usually kills all the leaves and the plants appear as if swept by fire (fig. 2). Commonly the disease does not become serious until after the second or third clusters have been harvested. At this time every leaf except a few at the top of the plant

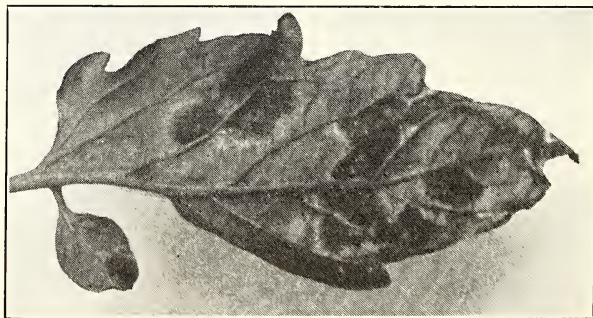


Fig. 1—Tomato leaf mold symptoms.

is infected. The upper tomatoes are consequently smaller and must ripen on the defoliated stalks. They lack both in size and quality.

Not only are the leaves destroyed but frequently the fungus attacks the calyces and rots the stem end of the fruit. This has been described by Gardner.¹

Proper ventilation of the houses has proven to be an important factor in controlling this disease. It would seem, then, that the prevention of leaf mold is largely a matter of greenhouse management and the disease would probably be worse in the poorly managed houses. This, however, is not true, since leaf mold is a serious pest in certain of the best greenhouses in the state. And in some of the conspicuously poorer houses it seldom if ever occurs. There is no question that improper ventilation and the consequent accumulation of moisture is a factor in increasing the disease, but it is equally certain that continual appearance of the disease and the concomitant accumulation of inoculum plays an important part.



Fig. 2—Leaf mold destroys every leaf on the plant and gives the appearance of the plants having been swept by fire.

The importance of spore accumulation in various parts of the greenhouses was well demonstrated by Emmett Wood, at Madison, Indiana. Wood fastens his tomato plants on three horizontal wires, which are strung lengthwise across the beds. The vines are tied to these wires with binder twine. The plants were badly infected with *Cladosporium* and it seemed probable that the spores would accumulate on the strings. With this possibility in mind, Wood poured gasoline over the spools of wire and burned off all the knots. The next season the leaf mold was

¹ Gardner, M. W. *Cladosporium Leaf Mold of Tomato: Fruit Invasion and Seed Transmission*. Jour. Agr. Res. 31:519-540, 1925.

retarded in its appearance in the houses where the string had been burned from the wire. It was as severe as ever in the beds where the knots had been left. It is possible that the spores spread from the infected bed to other parts of the house.

To determine if the spores of *Cladosporium fulvum* could be carried on the strings, the following experiment was conducted: Tomato plants grown in the Purdue Botany greenhouses were trained on strings which had supported plants heavily infected with leaf mold the previous season. Other plants were also trained on new strings. A month after the experiment was started a few spots of leaf mold developed on the plants trained on the strings from the infected greenhouses. No spots developed on the check plants. At this time white fly became so serious that the experiment was discontinued. Though the experiment was not complete, still it indicates that the spores of *C. fulvum* can be carried on the strings used to support the diseased vines.

Hasper² has shown that the conidia of this fungus can live eight months under dry conditions. This is sufficient longevity to permit it to exist from one crop to another in greenhouses. This evidence has been deemed sufficient to recommend to greenhouse gardeners that they discontinue the rather common practice of using the same strings year after year to support their vines. The majority are now using new binder twine each year.

Experiments have rather discouraged the use of dusts or sprays in the greenhouse as a means of control and have emphasized the need of proper ventilation. Three years ago Emmett Wood sprayed his greenhouse tomatoes under our direction. To avoid staining the fruit he used a 2-3-100 soda bordeaux.³ It was applied at a pressure of 300 pounds. A long hose was used, permitting the operator to walk the length of each house between the vines. A short rod with an angle nozzle was used so that the spray was applied on the lower surfaces of the leaves without difficulty.

The first application was made on May 9, 1924, when the plants were between three and four feet tall. At this time there were no signs of the leaf mold. The spraying did not entirely eliminate the disease but it was held in check sufficiently so that the vines remained green until the crop was completely harvested. Wood's statement concerning this work was: "Spraying greenhouse tomatoes has added not less than \$500 to our sales this year."

But there are many places where the gardeners are not equipped with power sprayers and it has been shown that thorough spraying cannot be done with a hand outfit. For these men, another method must be used, and to meet this condition dusting with 25 per cent copper-lime dust was used. The tests were carried out by Kiesling Bros. at Logansport, Geo. Wade at Muncie and Joe Shane at Fairmount.

Kiesling Bros. used an American Beauty knapsack duster and applied the dust five times during the season, beginning when the plants were about three feet tall. The leaves were well covered on the upper

² Hasper. Biologie und Bekämpfung des *Cladosporium fulvum* Cooke auf *Solanum lycopersicum*. Ztschr. für Pflanzenkr. 35:112-118, 1925.

³ Two pounds copper sulphate, three pounds sal soda, one hundred gallons water.

surfaces but it was difficult to thoroughly cover the lower surfaces. Nevertheless, the disease was held in check, only appearing late at one end of a single house. The chief difficulty experienced by the growers was that the fruit was heavily covered with the dust and each tomato had to be wiped off before marketing.

Geo. Wade used a different type of duster that did not deliver the dust in sufficient quantities, nor could the dust be directed against the lower surfaces of the leaves as efficiently. In this case the disease was not held in check to any appreciable extent.

Joe Shane did not start his applications until the plants had developed five or six clusters of fruit. The leaves were heavily spotted with the disease at the time. However, by the use of the American Beauty duster, he managed to prevent the destruction of the upper leaves and ripen his crop properly.

This evidence indicates that neither copper-lime dust nor soda-bordeaux will absolutely control leaf mold but the use of either of these materials is economical. They retard the disease sufficiently to permit the proper ripening of the tomatoes. It is also true that both the dust and the spray must be applied thoroughly and with the proper apparatus. The duster must deliver a sufficient quantity of dust to completely fill the house. The spray must be applied with at least 200 pounds pressure. In either case care must be exercised to direct the spray or dust against the lower surfaces of the leaves.

EXCESS SOLUBLE SALTS AS THE CAUSE OF VEGETABLE DISEASES IN GREENHOUSES.

S. D. CONNER and C. T. GREGORY, Purdue Agricultural Experiment Station.

In many greenhouses of Indiana, lettuce, grown in ground beds, is often affected in a peculiar manner. The growth is stunted and though the plants remain in the soil for ten weeks or more they never attain more than one-third to one-half the normal size. Ordinarily they do not die but simply stand still, though in a few instances lettuce plants have died. Under similar conditions, tomato and cucumber plants are also affected in the same way.

Lettuce plants have been examined in scores of cases. The leaves are small, usually dark green and very tough. The roots are brown, the tips usually being killed, and their development sparse (fig. 1). Nematodes are not associated with this trouble and as a matter of fact nematodes do not cause any serious injury to lettuce though they may kill tomatoes and cucumbers.

The roots, the stems and leaves of these diseased plants have been examined repeatedly and thoroughly, but no fungus or bacterial pathogen has been found associated with them.

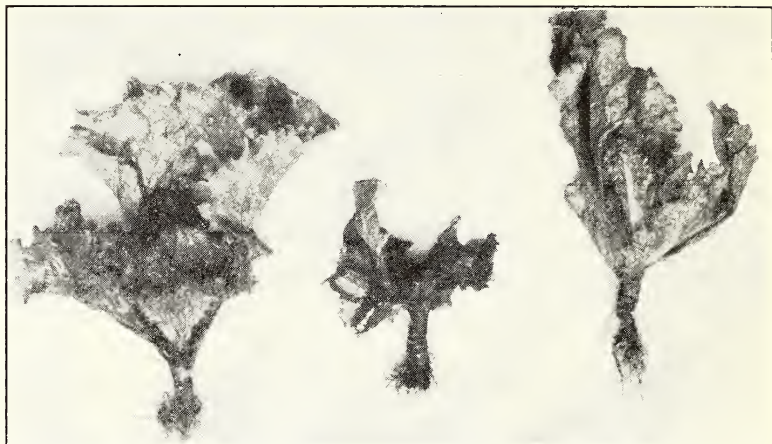


Fig. 1—Various types of lettuce plants developed in soil areas containing excess soluble salts. The plant in the center is more typical of this condition.

Another peculiarity of this disease is that it usually appears in spots in the bed (figs. 2 and 3). These spots are irregular in size and shape, and are always surrounded by perfectly normal plants. Indeed, it is not uncommon to find groups of normal plants growing in the midst of the affected area.



Fig. 2—A spot of poor lettuce in the Wood greenhouse at Madison, Indiana. This area showed the higher concentrations of soluble salts in the soil. Another case of poor lettuce on too rich soil.

So far as has been determined, there is but one other trouble that can be confused with this one in question. In certain greenhouses there are tiny white millipedes, known as *Scutigera* (*Scolopendrella*), that eat the tips of the young feeding roots. When such plants are removed from the soil, the tap root will be found to be almost completely stripped of rootlets. In addition, the tap root is scored with numerous tiny brown channels where the millipedes have eaten the tissue. Perhaps the best means of distinguishing this trouble is to examine the soil about the infested plants for the pest. There is almost invariably one or more about each plant.

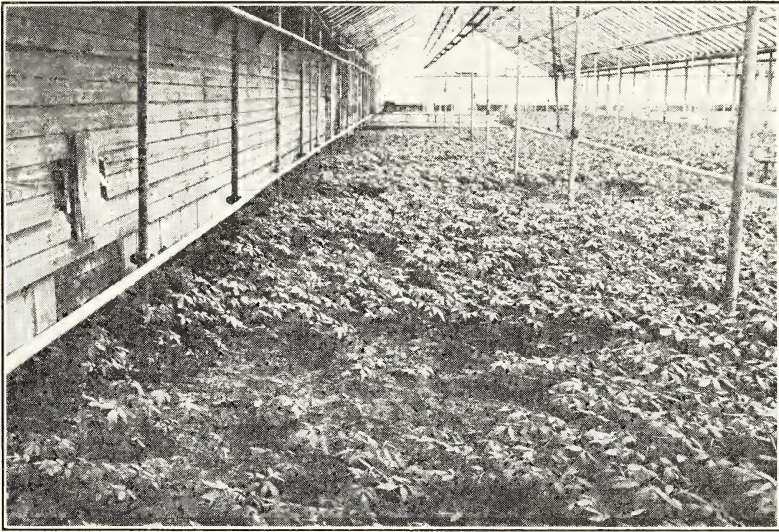


Fig. 3—Young tomato plants stunted and destroyed by excess soluble salts in a ground bed.

When a thorough examination of the trouble demonstrated that it was not caused by a pathogen, we came to the conclusion that the trouble must be in the soil.¹ Accordingly, composite samples were taken in this way: The surface two or three inches of soil was removed in three or more places in the area of poor plants and similar number where the plants were normal. Immediately after this other samples were taken six inches or more beneath the surface at the same points where the top samples were taken. The top soil samples were mixed together and about a half pint removed for the laboratory tests. The same method was used to secure the composite sample of bottom soil, as it was termed. We have found that the time of previous watering is important. Wherever possible, we take the samples when the soil has

¹ Brown, H. D., Baldwin, I. L., Conner, S. D. Greenhouse Soil Sterilization. Purdue Agr. Exp. Station Bul. 266:23-27, 1922.

not been watered for a few days. We find that watering will wash out the soluble salts so that the result may not indicate the true state of affairs.

It is significant that no cases of such injury have been found in sandy soil nor in places where an efficient underdrainage was provided. One method of underdrainage that has been found quite effective is to use an eighteen-inch layer of cinders covered by a foot or 18 inches of soil. These conditions are significant, as will be seen later, since they verify our opinion concerning excess soluble salts and the control of this trouble.

The method used to determine soluble salts is as follows: Use 100 gr. dry soil; add 100 cc. distilled water; shake at intervals for an hour or more, then shake thoroughly and quickly pour into a filter which will hold the entire amount. The first liquid that comes through is thrown away or returned to the filter. After a short time the solution will come through perfectly clear. A measured quantity of the solution is evaporated to dryness on a steam or water bath and weighed. This dry material is calculated to percentage of the dry soil.

Some samples of greenhouse soil have contained over one per cent of soluble salts. As a result of testing a large number of greenhouse soils which have given trouble, it has been concluded that when such soils show over .25 per cent soluble salts by the above procedure, there is danger of damage to young plants. It is recognized that there may be some colloidal material in the residue determined in this way, but such a per cent is nevertheless dangerous.

Garden and field soils in humid climates seldom show over .05 per cent soluble salts and never give trouble for this reason except in unusual instances. In arid regions excess soluble salts occur in soils and are known as "alkali." If we stop to think, ground beds in greenhouses are irrigated soils in regions of no rain. If there is good underdrainage in greenhouses and they are sprinkled thoroughly, the excess salts will be washed out. In like manner, in irrigated regions of low rainfall the remedy for alkali is underdrainage and heavy irrigation to wash out the alkali. The best time to leach greenhouse soils is just after the last crop has been taken off in the spring or summer. If greenhouse beds do not have a good sand, gravel or cinder sub-surface, it will be profitable to thoroughly tile each bed with a good outlet. Tile such as are used for soil sterilization will be sufficient if provided with an outlet.

Soluble salts accumulate from the residues of manure, fertilizer and the water used, as well as solution from the soil itself. They accumulate near the surface because the moisture is evaporating from the surface of the soil and a heavy watering will dissolve the salts as deeply as the soil is wet. The capillary rise of the water brings this soluble material to the surface where it is left after the moisture evaporates and the top soil dries out.

TABLE I. Tests for excess salts in greenhouse soils where lettuce was doing poorly and no pathogens were associated with the trouble.

Name	Location	Per Cent Soluble Salts under good lettuce		Per Cent Soluble Salts under poor lettuce	
		Top 3"	6" below surface	Top 3"	6" below surface
Markert and Zeck.....	Logansport.....	.22%	.25%	.33%	.70%
R. E. Wood.....	Madison.....	.25%		.33%	
Chris Peaper.....	Indianapolis.....	.13%		.97%	
Kops Bros.....	South Bend.....			.33%	.52%
Peaper Bros.....	Indianapolis.....	.10%		.30%	
Purdue Greenhouses.....	Lafayette.....	.15%		.30%	
Lindley.....	Springfield, Ill.....	.25%	.29%	.26%	.36%
B. F. Schilling.....	Lafayette.....	.14%		.35%	
Moore.....	Marion.....			.40%	.26%

It will be seen from Table I that the soil producing the poor lettuce always has considerably more soluble salts. Of course in these cases of lettuce development, growth of the plants is merely relative. It is probable that in certain cases the lettuce on the good soil might have done better, but in each case there was a decided difference in the growth of the good and poor plants. Take the case of Peaper at Indianapolis, where the poor soil had .97 per cent soluble salts as compared with .13 per cent in the good soil. The poor lettuce was completely stunted and would make no growth whereas the good lettuce was large and normally developed. It is significant, however, that the poor plants always appear in soils having a considerably higher percentage of soluble salts. When greenhouse soils were tested that did not show a higher percentage of soluble salts under the poor lettuce, other causes were always found.

It is probable that this trouble is not due to actual toxicity of the soluble salts, which are largely nitrates, chlorides, and sulphates. However, the nature of the growth of the lettuce plants does not seem to indicate this. The leaves remain green and apparently healthy but the growth is stunted. It appears as if the excessive concentration of soluble salts has increased the osmotic tension in the soil solution till it closely approximates that within the cells of the plant, particularly the roots. Under such condition the plant will have great difficulty in obtaining sufficient water for its growth.

This conception is further borne out by conditions obtaining when the surface layers accumulate very high concentrations of salts. At such times the stems of the plants dry out in a narrow area at the surface of the soil. This has been seen also in onion seedlings on muck soils during dry weather. Under such conditions, the solution actually becomes concentrated enough to draw the water from the tissues, resulting in an effect similar to the damping off disease.

It is well known by practical greenhouse men that old greenhouse soils left out in the open for several years will be greatly improved. The heavy rainfall of this climate would wash out the excess soluble salts. This would be the most probable explanation for such improvement.

Emmett Wood, of Madison, Indiana, has found that steaming his soil will dissipate the excess salts owing to the large amounts of water from the condensed steam. At Fort Wayne a gardener had trouble with excess salts and was able to cure the difficulty by heavy applications of water. So often the sub-soil is a heavy clay and the gardeners know from experience that copious watering would be disastrous, hence the recommendation to use tile drains to permit leaching without water-logging the soil.

ECOLOGICAL RELATIONSHIPS OF FUNGI IN CULTURES.

C. L. PORTER, Purdue University.

The efficiency of any organism in nature depends upon two factors, heredity and environment. This is true regardless of whether the organism be a fungous parasite or a man. Our control over heredity is limited and is the problem of the geneticist. We are constantly seeking to conserve and to improve nature by a more accurate and precise control of the environment of those organisms with which we work and have to deal.

The fungi present many problems of importance in both a constructive and a destructive sense. We are constantly adding to our knowledge concerning the environment of these lowly organisms. We know, for instance, the effect of various toxic agents upon the growth and reproduction of this form of life; we know in a great many cases the thermal death points; we have learned to know their likes and dislikes with regard to food materials. To ascertain the most favorable hydrogen-ion concentration is one of the chief pastimes of the mycologist. We must not forget, however, that one of the most important factors of environment is the presence of other forms of life both of the same and of different species. This phase of mycological ecology while frequently observed by many workers has not received the proportion of time and attention which its importance justifies. This failure may be ascribed partly to the difficulties inherent in the problem and partly because the significance has not been realized.

Modern ecology has given us many examples among higher plants and animals of the effect of one organism upon another in the succession. Even as far back as the time of Darwin and Wallace we were taught the delicate balance that pervaded nature and how when this balance was disturbed that consequences for good or ill might result to mankind. We are seeking always to maintain a balance favorable to our own ends. This, of course, is only a part of the general plan whereby man is constantly seeking to control all natural forces. At present, a possible method of controlling the corn borer is by means of certain parasites.

The balance which exists elsewhere in nature is also to be found among the fungi; not only among themselves but also in their relationships with their more highly organized associates. The study, then, of fungous environment, particularly in its relationships, should furnish us valuable information concerning the scientific control of obnoxious forms, and also information leading to the utilization of many fungi in the arts and industries.

In order to gain an accurate knowledge of the morphology and physiology of any species it is necessary to work with pure cultures. The bacteriologist and mycologist have so long followed this practice that they have forgotten that pure cultures are scarcely ever to be found in nature and what is gained by working with a known pure line culture is lost in the knowledge of the relationship which comes from contact with foreign organisms and even with those of its own kind.

Mixed cultures constitute the rule and not the exception in nature. Laboratory workers know with what difficulty they finally succeed in making an isolation of any disease organism. Even following careful technique our plates and tubes become contaminated with a frequency that is annoying.

A constant struggle exists in the mycological and pathological laboratories against the encroachment of undesirable forms into our cultures. Elaborate precautions have to be taken to insure success in this regard against "weeds" which seem to be omnipresent.

I have often found an apple diseased with both blotch and scab, the lesions being in close proximity. The surface of the same fruit may be marred with the fungi causing flyspeck and sooty blotch. In addition to these quite evident disorders it may be demonstrated that spores of *Penicillium*, *Alternaria*, and *Mucor* together with numerous bacteria are plentifully distributed over the surface. We have here, therefore, in this limited space not a homogeneous community but a heterogeneous population. The consequences of such heterogeneity has never been adequately studied either with respect to the host or to the complex and mixed population which inhabits it. What contests exist here for the available food supply? What are the effects of the several and diverse enzymes upon the various members of the group? The toxins and other waste products must necessarily cause reactions within the organisms themselves which will modify their natural habits and activities. Likewise, we have seen ears and even kernels of corn infested with two species of *Fusaria*, and *Diplodia*. It has been shown¹ that the organic population of a single node of a cornstalk is often numerous and quite diverse. The nearest market will usually furnish examples of oranges and lemons being rotted by two species of *Penicillium* contesting the limited space that they occupy. Manns² has demonstrated that two species of bacteria working in conjunction cause the blight of oats.

As has been suggested, these mixed populations inhabiting a host must react upon one another in such a way as to change their habits of growth and even affect their general metabolism. We have by numerous experiments of our own^{3,4} demonstrated this thesis and our obser-

¹ Porter, C. L. A study of the fungous flora of the nodal tissues of the corn plant. *Phytopath.* 17:563-568, 1927.

² Manns, T. F. The blade-blight of oats a bacterial disease. *Ohio Agr. Exp. Sta. Bul.* 210, 1909.

³ Porter, C. L. Concerning the characters of certain fungi as exhibited by their growth in the presence of other fungi. *Amer. Jour. Bot.* 11:168-188, 1923.

⁴ Porter, C. L. Phenomena exhibited by fungi when grown in close proximity. *Pro. Ind. Acad. Sci.* 34:259-260, 1924 (1925).

vations are supported by a rather voluminous if incidental literature.

The following variations from the normal have been observed in mixed cultures: change of color of the fungus, changes in color of the medium, distortion of the fungous hyphae, cessation of growth, increased sporulation, change in the character of the colony itself. Various explanations are possible to account for these changes and they have all been given from time to time by those who have observed and reflected on the phenomenon. It is possible that nutrients may have been withdrawn from the neutral area between two approaching colonies to such an extent that partial or complete starvation may cause cessation of growth. It is, of course, not necessary to assume that all nutrients have been drained away from this area; but the partial exhaustion of one nutrient may so affect the nutrient balance of the medium as to inhibit the growth of one or both of the organisms. If a nutrient so reduced is equally essential to both approaching fungi, both will be inhibited; if such a nutrient is, however, more essential to one than to the other the inhibition will not be the same for both colonies.

Brown⁵ speaks of staling products produced by an organism in a culture which will ultimately become self-inhibitory and which might affect another species even more than it does itself. Enzymes or toxins which diffuse outward through the medium undoubtedly play an important part in causing inhibition and particularly the malformations that accompany inhibition. Wherever antagonism is registered over an intervening area free from fungous growth it has been demonstrated that a piece of the medium removed from such an area and which is entirely sterile will cause the characteristic antagonistic symptoms when inlaid in the medium of another plate having the reacting fungus growing upon its surface.

The effect is not always inhibitory, however. The effect may stimulate growth. Pringsheim⁶ offers an interesting example of this particular point in an experiment where he grows *B. mesentericus vulgatus* in the same culture with *B. diptheriae*. He concludes that the former organism produces a thermolabile poison which stimulates the latter organism in small doses but which inhibits it in large doses.

An enormous amount of work remains to be done on this particular phase of mycological science before we will be in a position to fully analyze the phenomena and consequences of the growth of two or more organisms in close proximity and before we will be able to use the knowledge so gained in any practical control of fungous activities. The whole problem remains one of the most attractive forms of research in the field of mycology.

⁵ Brown, W. Experiments on the growth of fungi on culture media. *Annals Bot.* 37:105-129. 1923.

⁶ Pringsheim, E. G. Über die gegenseitige Schädigung und Förderung von Bakterien. *Centralbl. Bakt.* II 51:72-86. 1920.

HYDROGEN ION STUDIES OF WATER, PEAT, AND SOIL, IN RELATION TO ECOLOGICAL PROBLEMS AT BACON'S SWAMP, MARION COUNTY, INDIANA.

STANLEY A. CAIN, Butler University.

In connection with vegetational studies of Bacon's Swamp¹ it was found advisable to examine the hydrogen ion concentration of various zones to corroborate certain opinions as to the past vegetational history and the conditions under which the present vegetation is existing. Certain other information contained herein was obtained incidental to the real purpose of the studies and is included for what value it may have.

The swamp proper consists of a wet meadow surrounded by a more or less definite number of concentric vegetational zones. The normal sequence here runs from the center towards the periphery in the following stages: (a) *Calamagrostis canadensis*, (Mx.) Beauv. meadow with a peripheral zone of *Carex impressa*, (Wright) Mack; (b) *Cephalanthus occidentalis*, L. and *Salix nigra*, Marsh. occupying the moat, a region of deeper water; and (c) the forest region, first of the swamp forest type and last the upland forest climax.

The peripheral zones are distinctly of the half-drained type of vegetation but in the central meadow there are indications that the former vegetation has pertained more to the undrained or bog type. Conspicuous in this connection are sphagnum and "islands" of *Decadon verticellatus*, (L.) Ell., a notorious bog-mat shrub, here found in isolated patches in the fen-like meadow and fringing the outer natural open patch of water in what is perhaps the deepest portion of the swamp basin.

A study of the hydrogen ion concentration of surface water from various points over the swamp reveals a higher acid condition in the center of the southwest lobe. If the zones are considered from the outside inward, and, in the main, they are concentric and are to be found on almost any radius, it will be seen that the acidity increases towards the center where the vegetation is more of the acid type. (Table I.)

Perhaps the most interesting observation to be made is that of the diurnal variation in the pH at any one station. This phenomenon, first

¹ Cain, S. A. Airplane Photography and Ecological Mapping. Proc. Ind. Acad. Soc., 36, 1926. 1927.

² Philip, C. Diurnal Fluctuation in the Hydrogen Ion Activity of a Minnesota Lake. Ecology 8:74-89, 1927.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

TABLE I. Range in pH Values of Hydrophytic Associations.

The Association Station No.	Sample Number	Time of Reading	pH Value	pH Range	Amount of Range
1. <i>Salix Nigra</i> Algae	83a	5:15 a. m.	7.2	7.2-7.8	0.6
	83b	10:25 a. m.	7.4		
	83c	12:30 p. m.	7.5		
	83d	3:30 p. m.	7.8		
2. <i>Cephalanthus</i> Little Algae	88a	5:05 a. m.	6.9	6.9-7.2	0.3
	88b	10:12 a. m.	6.9		
	88c	12:50 p. m.	7.1		
	88d	2:45 p. m.	7.2		
3. <i>Typha-Lemna</i> Much Algae	86a	5:01 a. m.	6.8	6.8-7.8	1.0
	86b	10:10 a. m.	7.5		
	86c	12:45 p. m.	7.8		
	86d	2:42 p. m.	7.6		
4. <i>Nymphaea</i> Little Algae	71a	4:52 a. m.	6.9	6.9-7.1	0.2
	71b	10:05 a. m.	6.8		
	71c	12:40 p. m.	7.0		
	71d	2:40 p. m.	7.1		
5. Sedge Meadow Much Algae	62	11:05 a. m.	6.9	5.8-6.9	1.1
	69	11:10 a. m.	6.5		
	43	11:20 a. m.	6.0		
	65	11:25 a. m.	6.2		
	72	4:00 p. m.	5.8		
6. Grass Meadow	63	11:00 a. m.	6.9	5.9-6.9	1.0
	73	11:15 a. m.	6.4		
	70	11:30 a. m.	6.6		
	47	3:30 p. m.	5.9		
7. Water Holes in Meadow Due to Burning Algae	61	11:30 a. m.	5.5	5.5-5.8	0.3
	60	3:45 p. m.	5.8		
8. Decodon Island No Algae S. W. Lobe	67	11:35 a. m.	5.1	5.1-6.0	0.9
	42	11:40 a. m.	5.5		
	72	11:45 a. m.	5.3		
	48	11:50 a. m.	5.1		
	40	3:45 p. m.	5.9		
	82	4:05 p. m.	6.0		

noted by Philip,² is related to the photosynthetic-respiratory ratio, consequently the hydrogen ion concentration at any hydrophytic station will vary with the factors affecting the quantitative CO₂ and O₂ production and utilization.

A series of pH readings is necessary for any adequate information as to the acid conditions under which any group of plants exists. No longer can random observations be given importance.

From Table I it can be seen that there is a diurnal fluctuation exhibited on this particular day (May 13, 1927, cloudy) ranging from 0.2 variation in one instance to 1.1 variation in another and from the most acid to the least acid situation we have the extremes from Decodon with pH 5.1-6.0 to *Salix* with pH 7.2-7.8.

The diurnal range on a bright, warm day would no doubt be more than twice that shown here for a rather dull day.

A study of the pH of the submersed peat in which the various wet-meadow plants are rooted shows higher acidity in the southwest bog-like region (Table II), when the acidity may be 100 times that in the north lobe. It will also be noted that the peat runs more acid than the water which covers it.

TABLE II. H-ion of Peat Samples.

Sample No.	Location of Station	Depth	pH Colorimetric
55	Calamagrostis.....	Surface	6.0
56	Calamagrostis.....	36" deep	6.4
57	North lobe swamp.....	Surface	6.4
58	Calamagrostis.....	16" deep	6.6
85	Edge of open water S.w. lobe.....	Surface	4.8
42	S.w. lobe.....	18" deep	5.3
80	Is. of Decadon S.w. lobe.....	Surface	5.0
23	S.w. lobe.....	18" deep	4.4

TABLE III. pH Values of Soil Samples.

Depth of Sample in Inches	Lowland Forest		Upland Forest	
	Number	pH	Number	pH
A	0	27	10	7.3
	5	41	30	7.1
	10	21	6	7.3
	15	37	29	7.4
	20	3	11	7.4
B	0	39	34	6.4
	5	4	35	6.4
	10	33	19	6.5
	15	17	46	6.3
C	0	32	24	7.0
	5	25	20	6.5
	10	12	8	6.3
	15	14	15	6.6
	20	22	28	6.6
D	0	16		
	10	31		
	20	26		

TABLE IV. Total Ranges of pH at Different Levels of Soil.

Depth of Sample	Swamp Forest	Upland Forest
0"	5.9-7.0	6.4-7.3
5"	6.3-6.8	6.4-7.1
10"	6.3-7.2	6.3-7.3
15"	6.5-7.2	6.3-7.4
20"	7.0-7.4	6.6-7.4

A brief study was made of the soil stratification and the pH relations of the upland and lowland forests. Four pairs of stations were selected typical of the two types of forest. The results of the readings are given in Tables III and IV. For colorimetric readings see the description of the La Motte apparatus.³ The electrometric readings were made on a Kelley electrical titration apparatus. It will be seen from the preceding data that there is no particular contrast between the soil

³ Taylor, W. A. The A. B. C. of Hydrogen Ion Control. The La Motte Chemical Co. Baltimore, Md. 1926.

reaction of the two types of forest which differ so much floristically. Some other factor is evidently the limiting one. (It seems that the upper level of inundation at periods of high water coincide with the limits of the rather narrow swamp forest.)

In the case of the swamp forest there seems to be a definite gradient in pH, alkalinity increasing with increasing depth. The greatest range is from pH 5.9 at the surface to pH 7.4 at a depth of 20 inches. This is the same sort of situation Salisbury⁴ found. It is, of course, not assumed that so few readings are sufficient to establish conclusive evidence as to stratification in the soil. It is maintained, however, that these four sets of samples are sufficient, in this case at least, to show that pH is not the significant factor in determining the limits of the swamp and upland forests.

These soil samples were obtained by use of a spring-steel excavator instead of the customary soil-auger. This tool is a coiled spring with a flat outer surface and a convex inner face with a maximum width of

TABLE V. Colorimetric and Electrometric Check of pH.

Soil Solutions						Peat Solutions		
Lowland			Upland					
No.	Colorimetric	Electrometric	No.	Colorimetric	Electrometric	No.	Colorimetric	Electrometric
27	6.7	6.70	10	7.3	7.32	9	6.4	6.50
41	6.8	6.85	30	7.1	7.08	45	6.4	6.38
21	6.9	6.92	6	7.3	7.32	7	6.1	6.15
37	6.7	6.65	29	7.4	7.42	13	6.2	6.18
3	7.0	6.90	11	7.4	7.32	36	6.6	6.60
39	5.9	6.07	34	6.4	6.53	51	6.5	6.38
4	6.3	6.23	35	6.4	6.30	52	6.2	6.02
33	6.1	6.03	19	6.5	6.38	53	6.4	6.37
17	6.5	6.54	46	6.3	6.25	54	6.3	6.32
32	6.7	6.72	24	7.0	7.10	55	6.0	6.04
27	6.7	6.68	20	6.5	6.50	56	6.4	6.33
12	7.1	6.88	8	6.3	6.25	57	6.4	6.37
14	7.2	7.04	15	6.6	6.58	58	6.6	6.58
22	7.4	7.33	28	6.6	6.43			
16	7.0	6.88						
31	7.2	7.43						
26	7.1	7.12						

about one-fourth inch. The spring is about 15 inches long and two inches in outer diameter. It is tapered onto a short length of one and one-fourth inch pipe and fitted on in convenient lengths as greater depth of samples is desired. The advantages of this hollow spring excavator are two: first, it is easy to use and, second, it secures a core of fair size diameter the inner parts of which are not contaminated by soil water from above if the operation is performed quickly. The outer moister parts of the core which have been subjected to friction and contamination can be quickly removed and a "pure" sample obtained from the interior.

In order to determine the reliability of the colorimetric method a

⁴ Salisbury. Stratification of Hydrogen-ion Concentration of the Soil in Relation to Teaching and Plant Succession. Jour. Ecol. 9, 1922.

TABLE VI. Changes in pH of Collected Samples.

WATER SAMPLES—

Association	Sample No.	pH May 13th	pH May 16th	H-ion Increase	Decrease
Salix.....	83a	7.2	7.3		0.1
Cephalanthus.....	88a	6.9	7.9		1.0
Typha.....	86a	6.8	7.2		0.4
Nymphaea.....	71a	6.9	7.3		0.4
S. W. Meadows.....	47	5.9	5.6	0.3	
S. W. Meadows.....	72	5.8	5.6	0.2	
S. W. Meadows.....	60	5.8	5.7	0.1	

PEAT SOLUTIONS—

Sample Depth	Sample No.	pH May 10th	pH May 18th	H-ion Increase	Decrease
Surface Peat.....	9	6.4	5.9	0.5	
Surface Peat.....	51	6.5	6.5	0	
Surface Peat.....	55	6.0	6.0	0	
Peat 1" deep.....	45	6.4	6.4	0	
Peat 2" deep.....	7	6.1	6.2		0.1
Peat 3" deep.....	13	6.2	6.2	0	
Peat 15" deep.....	54	6.3	6.0	0.3	
Peat 66" deep.....	56	6.4	6.4	0	
Peat 66" deep.....	58	6.6	6.4	0.2	

SOIL SOLUTIONS (LOWLAND SAMPLES)—

Sample Depth	Sample No.	pH May 9th	pH May 17th	pH May 18th	Increase	Decrease
Surface.....	27	6.7	6.7		0	
Surface.....	39	5.9	6.0			0.1
Surface.....	32	6.7		6.3	0.4	
Surface.....	16	7.0		6.6	0.4	
Depth, 5 inches.....	41	6.8	6.4		0.4	
Depth, 5 inches.....	4	6.3	6.3		0	
Depth, 5 inches.....	25	6.7		6.5	0.2	
Depth, 10 inches.....	21	6.9		6.6	0.3	
Depth, 10 inches.....	31	7.2	6.8		0.4	
Depth, 15 inches.....	37	6.7	6.6		0.1	
Depth, 15 inches.....	14	7.2	7.1		0.1	
Depth, 20 inches.....	22	7.4	7.0		0.4	
Depth, 20 inches.....	26	7.1	6.7		0.4	

SOIL SOLUTIONS (UPLAND SAMPLES)—

Sample Depth	Sample No.	pH May 9th	pH May 17th	pH May 18th	Increase	Decrease
Depth, surface.....	10	7.3		7.0	0.3	
Depth, surface.....	34	6.4		6.1	0.3	
Depth, surface.....	24	7.0		6.6	0.4	
Depth, 5 inches.....	30	7.1	6.9		0.2	
Depth, 5 inches.....	35	6.4	6.2		0.2	
Depth, 5 inches.....	20	6.5		6.2	0.3	
Depth, 10 inches.....	19	6.5		6.1	0.4	
Depth, 15 inches.....	29	7.4		6.9	0.5	
Depth, 15 inches.....	46	6.3		6.3	0	
Depth, 20 inches.....	11	7.4	6.8		0.6	
Depth, 20 inches.....	28	6.6		6.4	0.2	

number of soil solutions were read by the electrometric method as well as by the La Motte system. The readings were made at the same time by different individuals. The results were checked on completion. (Table V.)

The 44 checks of the colorimetric method show an average deviation from the electrometric of 0.061 pH. It is probably realized that this is sufficiently close to warrant the field use of the colorimetric method, as the divergence from the true soil reaction is less than the difference in pH that can be interpreted to have any effect on the distribution of plants.

The soils here tested ranged from heavy blue clay to rich vegetable loam and peat. Olsen,⁵ working on Danish soils, has found a satisfactory check in the two methods for a variety of soils.

An observation was made on the change in pH of collected samples with a view to determining the safety with which readings could be delayed. The soil and peat samples had to be taken into the laboratory before they could be read colorimetrically. This necessitated a lapse of a few hours, which was found to make no great difference in the pH of the samples. After soil extracts were derived by centrifuging, a lapse of 12 hours in four instances tested made no difference. In order to see if longer lapses of time would change the solutions, although corked, some were read after a lapse of three days, and others were read after eight and nine days.

It will be noted from table VI that there is considerable variation in some cases and hardly any appreciable change in others. The water samples from the hydrophytic associations behave in two ways. The samples from the meadow show an increase in acidity. The samples from the deeper zones, 83, 88, etc., show a decrease in acidity. The differences here are probably related to the ratio of respiration to photosynthesis. This idea is substantiated by the apparent quantities of plants in the latter regions, and of animals in the former.

The peat samples gave extracts (with three times as much water as peat) which were apparently well buffered and contained few organisms, as five out of nine of the extracts were unchanged after a lapse of eight days.

The soil extracts showed what may be considered slight changes. They were, with one exception, changes towards increased acidity. This is explainable by respiration of micro-organisms which remained in the centrifuged extracts. Photosynthetic micro-organisms were not present in any quantity sufficient to use up much CO₂ and so give increased alkalinity. The average change in soil extracts over a period eight to nine days was 0.278 of a pH in increased acidity.

From this evidence it can be concluded that soils may be kept for quite a length of time after collecting without there being any considerable change in pH; but after the extract is made the readings should be made within a few hours.

⁵ Olsen, Carsten. Studies on the H-ion Concentration of the Soil and its Significance to the Vegetation, Especially the Natural Distribution of Plants. *Comptes-Rendus, Laboratoire Carlsberg*. 15, No. 1. 1923.

SUMMARY AND CONCLUSIONS.

In the lowland forest particularly there seems to be a definite downward gradient in pH, alkalinity increasing with increasing depth.

The peat samples were all acid, although those taken from the northern end of the swamp were only slightly acid. The samples from the southwest end of the swamp were more acid, reaching pH 4.4.

Soils can best be tested in the laboratory because of the necessity in most instances of filtering or centrifuging the soil extracts to clear them for colorimetric readings. Centrifuging is most satisfactory.

A series of 44 checks of the colorimetric method with the electro-metric method, on different types of soils and peat, gave an average deviation of 0.061 pH. From this it may be concluded that the standard colorimetric methods are sufficiently accurate, i. e., closer to the actual effective acidity, than can be interpreted in the field in relation to vegetation.

In the hydrophytic associations there is a diurnal trend in pH. The habitats are most acid in the morning, at the close of a period of darkness and are less acid after the photosynthetic period. This trend is evidently directly correlated with the respiratory-photosynthetic ratio.

Water samples should be tested for pH in the field, as they will rapidly change in pH, due to the respiratory-photosynthetic relations of the micro-organisms present in the water.

Peat samples, even when extracted, show very little change in pH, although allowed to stand for a number of days. This is evidently correlated with the relative absence of micro-organisms. Divers soils vary in this respect.

In both soil and aquatic habitats there seems to be certain pH ranges within which the various associations are found. In most instances in this particular study the ranges of different associations overlapped or are so broad that little emphasis can be placed on acidity as a limiting factor in the present vegetation. (The greater acidity of the peat in the southwest end of the swamp can be considered as significant, as already indicated.)

THE BOG CLEARWEED, *ADICEA FONTANA* LUNELL,
IN INDIANA.

MARCUS WARD LYON, JR., South Bend.

At one place in the quaking bog at Mineral Springs,¹ Porter County, numerous small plants of the genus *Adicea* are found growing in great abundance for an area of many square meters. They grow amid bull-rushes (*Scirpus validus*), and are so thick as to form almost a carpet. These plants stand from five to seven centimeters in height. At first glance they look as if they were seedlings or depauperate forms. Careful examination, however, shows that they are perfect plants bearing seeds in abundance. Comparison of specimens of these plants with the description of Lunell's *Adicea fontana*² leaves little doubt that they are identical with that species. Both surfaces of the leaves of these small plants have scattered, small, rather stiff, slightly curved blackish hairs. Seeds, blackish, 1.50-1.75x1.25-1.50 mm.

In the Nieuwland Herbarium, University of Notre Dame, are the paratypes of Lunell's *Adicea Deamii*,³ collected in the Mineral Springs subdunal woods. A specimen of *Adicea* in my own herbarium collected in the subdunal woods at Tamarack agrees for the most part with the same species. That specimen measures 35 centimeters in height, is unbranched, has small, narrow green seeds, 1.25-1.37x0.75-0.87 mm. Both surfaces of the leaves of this plant have scattered whitish hairs.

The relationship of the dwarf plants to the larger, more usually seen forms is not clear, as here and there in the quaking bog a few plants of intermediate size are found, some attaining a height of 20 centimeters. Unfortunately, none of my intermediate sized specimens collected have mature seeds. Both surfaces of the leaves, however, have the blackish hairs characteristic of the dwarf plants. These two forms of *Adicea* show such differences in color, form, and size of the seeds that if they do not represent distinct species, they are exceedingly well-marked ecological forms. The differences in size and shape of the seeds of the two forms are shown by camera lucida drawings in fig. 1, the upper row being the green seeds of the woodland plant, *A. Deamii*, and the lower row the blackish seeds of the bog plant, *A. fontana*. The specimen of *A. Deamii* was collected September 20, 1927. Specimens of *A. fontana* were collected September 11 and 25, 1927.

In the Deam Herbarium are three sheets of small plants of *Adicea* of marsh habitat: 1, Kosciusko County, Big Chapman Lake; 2, Wabash County, Long Lake; 3, Jay County, four miles northeast of Penwell, on an old log in a swamp. All these have the large seeds of *A. fontana*.

¹ Lyon, M. W. Jr. Amer. Midland Naturalist. 10:249, May, 1927.

² Lunell, J. Amer. Midland Naturalist. 3:7. January, 1913.

³ Tom. cit., p. 10.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

In the same herbarium from LaGrange County, from a big swamp, shore of Pigeon River, is a sheet of specimens of apparently this species, measuring 27 centimeters tall but having the same type of seeds.

My thanks are due Dr. J. A. Nieuwland for calling attention to Lunell's paper, and to Mr. C. C. Deam for the opportunity of examining his specimens.

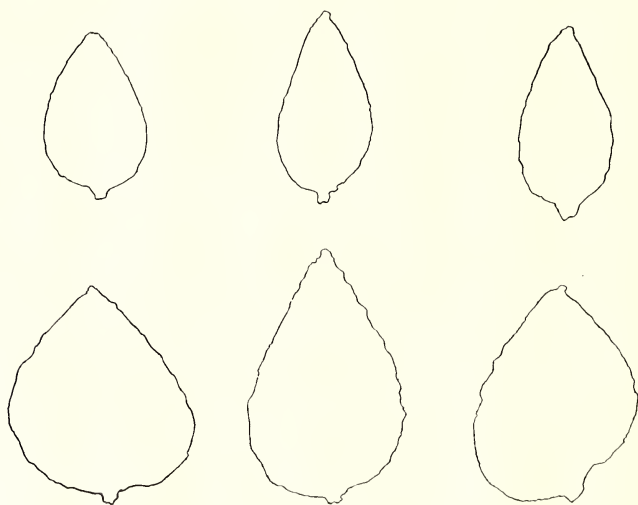


Fig. 1—Seeds of *Adicca Deamii*, upper row, and of *Adicca fontana*, lower row.

THE RELATION OF LIME TO THE ABSORPTION OF IRON BY PLANTS.

WILLIAM P. ALLYN, Indiana State Normal, Terre Haute.

Much attention has been given recently to the relation that iron bears to chlorosis in plants. That the assimilation of iron is closely associated with the proper development of chlorophyll seems to be well established. The addition of ferrous sulphate to the medium in which chlorotic plants are growing has been reported to correct this condition. Westgate and Johnson¹ reported that chlorotic pineapples were brought back to normal condition by spraying with a solution of ferrous sulphate. Korstian, Hartley, Watts, and Hahn³ have accomplished similar results on conifers.

It has also been noted that the soil conditions developed by excess liming of soils tends to develop chlorosis in plants.^{2,5} The observations made by the writer at a number of agricultural experiment stations warrant the same conclusion. The fact that iron precipitates as an insoluble hydroxide in an alkaline solution has led to the theoretical conclusion that the excessive use of lime causes iron to be precipitated from the soil water as an hydroxide, and hence to become unavailable for plant absorption. A prevalent belief seems to be that lime-induced chlorosis in plants is brought about in this manner. An excessive use of lime locks up the iron as an insoluble compound in the soil and renders it unavailable for plant use in the normal development of chlorophyll.

It is not the purpose in this paper to contend that calcium carbonate bears no relation to chlorosis in plants, but that the conditions obtained by the addition of excessive amounts of calcium carbonate do not render iron in the soil unavailable for plant absorption. Tests for iron at the nodes of growing corn plants indicate that plants are able to get rather large quantities of iron from the soil where large and continuous applications of lime have been used.⁴ The addition of lime,

¹ Westgate, J. M. and Johnson, M. O. The spraying of yellow pineapple plants on manganese soils with iron sulphate solutions. Hawaii Agr. Exp. Sta. Press Bul. 51. 11 p. 1916.

² Gile, P. L. and Carrero, J. O. Cause of lime-induced chlorosis and the availability of iron in the soil. Jour. Agr. Res. 20:33-59. 1920.

³ Korstian, Clarence F., Hartley, Carl, Watts, Lyle F., and Hahn, Glen G. A chlorosis of conifers corrected by spraying with ferrous sulphate. Jour. Amer. Res. 21:153-171. 1921.

⁴ Hoffer, G. N. Testing corn plants chemically to aid in determining their food needs. Purdue Agr. Exp. Sta. Bul. 298:1-31. 1926.

⁵ Gilbert, Basil E., McLean, Forman T., and Hardin, Leo J. The relation of manganese and iron to a lime-induced chlorosis. Soil Science 22:437-445. 1926.

in no instance, seemed to reduce the amount of iron found at the nodes of the plant, but rather to the contrary, to increase it to rather marked degree.⁴ The findings have not been construed to mean that the total amount of iron absorbed by the plant is increased by the excessive use of lime. There is some evidence on record, however, to support this conclusion.⁵

The conclusions reached in this paper are the result of data acquired by tests made on corn plants selected from fertility plots at agricultural experimental stations. The plots tested have a definite fertility history and have been running in many instances from 20 to 30 years. The potassium thiocyanate method was used in determining the amount of iron deposited at the nodes of the plants. This method used is not strictly quantitative; however, differences between light and heavy deposits of iron can be discerned with very little difficulty.⁴

Field Data. The relative amounts of iron found at the nodes of corn plants grown under various treatments are shown in the accompanying tables. These data represent the typical findings of the field work. Four representative stalks were selected from each plot for the tests. The approximate acidity of the surface soil was obtained by the use of brom thymol blue as an indicator. Space does not permit the introduction of all data obtained by these tests.

TABLE I. Relative amounts of iron found in nodes of corn grown under various treatment at the Pennsylvania State College, State College, Pennsylvania.

Plot	Fertilizer Treatment	Lime Treatment	Approximate Acidity	Indication of relative amts. iron at nodes.
1	48 lb. P_2O_5	Limed	Neutral	**
2	100 lb. K_2O	Limed	Slightly Acid	*
3	48 lb. P_2O_5 24 lb. Dried Blood	Limed	Neutral	***
4	48 lb. P_2O_5 100 lb. K_2O	No Lime	Slightly Acid	*
5	8 T. Manure	Limed	Slightly Acid	—
6	48 lb. P_2O_5 100 lb. K_2O	Limed	Slightly Acid	—
7	72 lb. Dried Blood 48 lb. P_2O_5 100 lb. K_2O	Limed	Slightly Acid	*
8	Cheek	Burnt Lime	Slightly Alkaline	****
9	Cheek	None since '23	Slightly Acid	**

— indicates mere trace of iron.

**s relative larger amounts of iron.

TABLE II. Relative amounts of iron found in nodes of corn grown under varying treatments at the University of Delaware, Newark, Delaware.

Plot	Fertilizer Treatment	Lime Treatment	Approximate Acidity	Indication of relative amounts iron at nodes
10	None	(*) Lime	Neutral	***
11	10 T. Manure every four years	Lime	Neutral	*
12	150 lb. P_2O_5 ; 5 T. Manure every 4 yrs.	Lime	Neutral	*
13	35 lb. Cyanimid 36 lb. K_2O	Lime	Neutral	*
14	10 lb. $NaNO_3$ 10 lb. $(NH_4)_2SO_4$ 20 lb. D. Blood 150 lb. P_2O_5 ; 36 lb. K_2O	Lime	Neutral	—
15	None	Lime	Neutral	***
16	20 lb. Dried Blood 200 lb. P_2O_5 48 lb. K_2O 20 lb. $NaNO_3$	Lime	Slightly Acid	—
17	15 lb. Blood; 15 lb. $NaNO_3$ 150 lb. P_2O_5 ; 36 lb. K_2O	Lime	Neutral	—
18	30 lb. $NaNO_3$ 36 lb. K_2O	Lime	Neutral	—
19	150 lb. P_2O_5 36 lb. K_2O	Lime	Slightly Acid	—
20	None	Lime	Neutral	***
21	60 lb. Fish Scrap 125 lb. P_2O_5	Lime	Neutral	***
22	36 lb. K_2O	Lime	Neutral	*
23	36 lb. K_2O	No Lime	Slightly Acid	—
24	150 lb. P_2O_5	Lime	Neutral	****
25	15 lb. $NaNO_3$ 15 lb. Blood	Lime	Neutral	***
26	None	Lime	Neutral	****
27	None	No Lime	Slightly Acid	**

*Limed plots have received 1,500 lbs. hydrate of lime respectively every four years.

TABLE III. Relative amounts of iron found at nodes of corn grown under varying treatments at the University of Kentucky, Lexington, Kentucky.

Plot	Fertilizer Treatment	Lime Treatment	Approximate Acidity	Indication of relative amts. iron at nodes.
28	100 lb. P_2O_5 Crop Residue	(*) Lime	Neutral	**
29	100 lb. P_2O_5 Crop Residue	No Lime	Medium Acid	—
30	100 lb. K_2O Crop Residue	Lime	Neutral	*
31	100 lb. P_2O_5 ; 100 lb. K_2O Crop Residue	Lime	Medium Acid	*
32 32	100 lb. K_2O 100 lb. P_2O_5 Crop Residue	No Lime	Medium Acid	—
33	Crop Residue Only	Lime	Neutral	***
34	Crop Residue Only	No Lime	Medium Acid	—

(*) Limed plots have received the equivalent of 9 tons of $CaCO_3$ since 1911.

Discussion of Data. It will be noted in Table I that the heaviest deposits of iron occur at the nodes of plants selected from limed plots, especially where the soil reaction has approached neutrality or beyond and the use of potash or manure has been left out of the treatment. Potash and manure, when applied in appreciable amounts, reduce the nodal deposition of iron very materially. The plants selected from the unfertilized plot 8, in which the soil reaction has become slightly alkaline, show a much heavier deposition of iron than those taken from the corresponding check plot 9, which shows a slightly acid reaction.

The story revealed by the data in Table II is very comparable to that of Table I. The heaviest deposits of iron occur in plants grown on the limed plots which have a neutral soil reaction and which have not been treated with manure or potash. Special attention is directed to the unfertilized plots, numbers 26 and 27. A rather marked contrast is indicated between the unlimed check plot and the corresponding check plot which received lime.

The data recorded in Table III would indicate also that lime does not render iron in the soil unavailable for plant absorption. A rather sharp contrast seems to exist between the use of lime and no lime on the check plots 33 and 34. It will be noted that a mere trace of iron was found at the nodes of plants taken from the unlimed plots.

It might appear from the discussion of these results that the contention is being made that the excessive use of lime tends to make iron more available for plant absorption. The chemical properties of iron would hardly justify that conclusion. Moreover, the addition of potash or manure in appreciable quantities seemed to reduce the deposition of iron at the nodes. That plants get iron in rather large quantities from the soil where lime has been used to excess seems quite certain. Whether

or not the iron after having been absorbed by the plant is improperly assimilated and permitted to deposit at the nodes of the plant because of the action of lime in the soil is the question. It would appear that lime locks up other elements in the soil (one of which is probably potash) which are necessary for the proper iron distribution in the plant rather than rendering the iron itself unavailable for plant absorption.

The writer wishes to express his appreciation to Dr. G. N. Hoffer of the Purdue University Agricultural Experiment Station for valuable assistance and helpful suggestions given in this work.

Summary. 1. Stalk tests indicate that the excessive use of calcium carbonate on soils does not render iron unavailable for corn plant absorption.

2. The application of lime increases the deposition of iron at the nodes of corn plants rather than decreases it, especially where the soil reaction had become neutral or slightly alkaline.

3. The heavy deposits of iron at the nodes of plants grown on heavily limed plots does not necessarily indicate that the total absorption of iron by the plants was greater.

4. The application of manure or potash in appreciable amounts decreases very materially the amount of iron deposited at the nodes.

5. These data indicate that lime-induced chlorosis is not a result of iron becoming locked up in the soil; but rather the result of a disturbance in the metabolism of iron after it has been absorbed by the plant.

INDIANA PLANT DISEASES, 1926¹

MAX W. GARDNER,² Purdue University Agricultural Experiment Station.

This is the eighth³ of a series of annual summaries of the plant disease situation in the state. No claim for completeness is made.

The weather during the 1926 season, as shown in the graphs in figure 1, was characterized by a cold March, April and June; by dry weather in May and June, and exceedingly high rainfall in late August, September, and October. The dry weather in the spring checked apple scab and rust and the cereal rusts, and the hot weather was not sufficiently prolonged to favor the *Fusarium* wilt diseases. The wet weather late in the season greatly favored apple bitter rot, *Phytophthora* and other rots of tomato fruit, late blight of potatoes, and black rot of sweet potatoes.

Apple.—Scab, caused by *Venturia inaequalis*, was very light this year, except in the northeast corner of the state, where Burkholder found it serious, especially on the Winter Banana and Kinnard varieties.

Blotch, caused by *Phyllosticta solitaria*, was worse than in 1925, but not as bad as in 1924. By exposing healthy, potted Oldenburg nursery trees under badly cankered old trees, and changing these nursery trees after each rain, Kohl⁴ found that infection at Mitchell occurred only during the rains of May 31 and June 11 and 12, 21 days and 32 days after petal-fall, although 14 rain periods were thus tested. At Lafayette, however, he found that infection occurred during 10 out of 24 rain periods tested. The dates when infection occurred ranged from five days to eight weeks after petal fall (May 18).

In blotch spray tests at Mitchell, both the Bordeaux and lime sulphur sprays at two, four, and six weeks after petal-fall proved effective. The effectiveness of early canker eradication and prevention in young orchards by cutting out the old cankers and spraying to prevent new ones was proved at Vincennes by the practical freedom from blotch of the fruit in two unsprayed blocks⁵ of Oldenburg trees, the same blocks left unsprayed last year. That the disease is carried far and wide on nursery stock was further proved by the discovery of cankers on young

¹ Contribution from the Botanical Department, Purdue University Agricultural Experiment Station, Lafayette, Indiana.

² The writer wishes to acknowledge the coöperation of H. S. Jackson, E. B. Mains, G. N. Hoffer, J. B. Kendrick, W. E. Leer, F. P. Cullinan, Monroe McCown, C. L. Burkholder, C. E. Baker, H. D. Brown, A. H. Watson, E. J. Kohl, C. L. Porter, D. C. Cooper, B. A. Porter, Leslie Pierce, and H. F. Dietz.

³ Proc. Ind. Acad. Sci. 1919:135-156, 1921; 1920:187-208, 1921; 1923:163-201, 1924; 1923:202-211, 1924; 1924:297-313, 1925; 1925:237-257, 1926; and 1926:231-247, 1927.

⁴ Kohl, Edwin J. Details in the life-history of the apple blotch fungus. Abs. in Phytopath. 17:45-46. 1927.

⁵ Gardner, Max W. Apple blotch canker eradication. Phytopath. 17:185-188. 1927.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

trees near Marquette, Michigan, and not far from Lake Superior. As far north as this, it is not at all probable that there will be any spread of infection.

There was an extremely destructive epiphytotic of fire blight due to *Bacillus amylovorus* in early June in the southern half of the state and particularly in the southwest portion. The disease was reported from 22 counties. Very severe infection occurred in the rather exten-

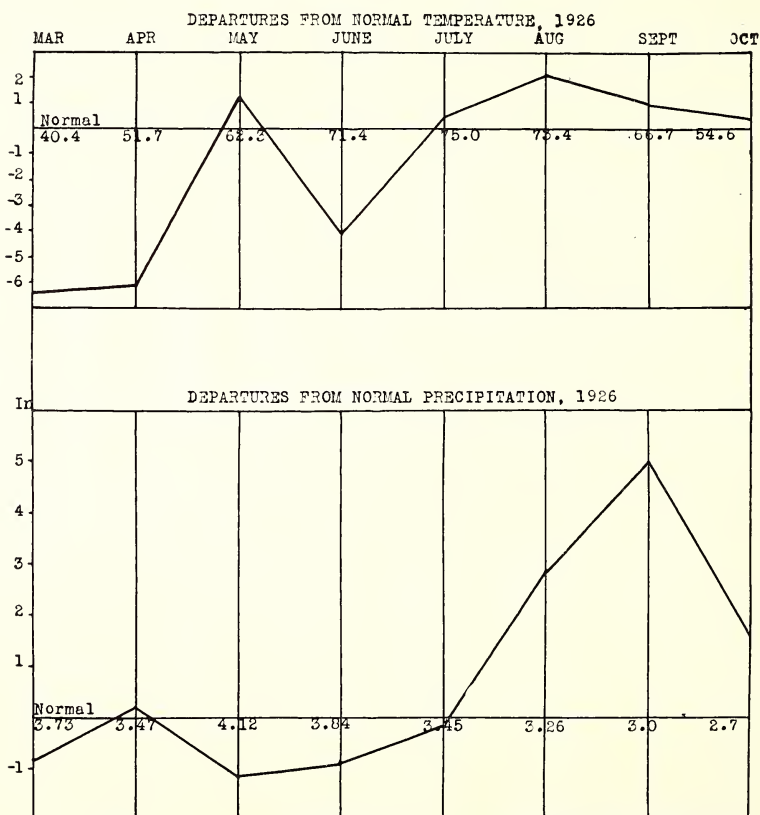


Fig. 1—Departures from normal temperature and precipitation based on monthly averages supplied by J. H. Armington in Climatological Data.

sive plantings of the Jonathan variety about Vincennes, so severe, in fact, as to lead some growers to top work this variety to the more resistant Turley variety. The disease was also very serious on Transparent and on young trees of the Willow variety. Abundant exudate occurred on the twigs and petioles in many varieties. In numerous instances noted on June 11, the partially grown Transparent fruit was invaded, usually by way of the pedicel, from blighted blossoms in the same cluster, occasionally through wounds, and showed a conspicuous

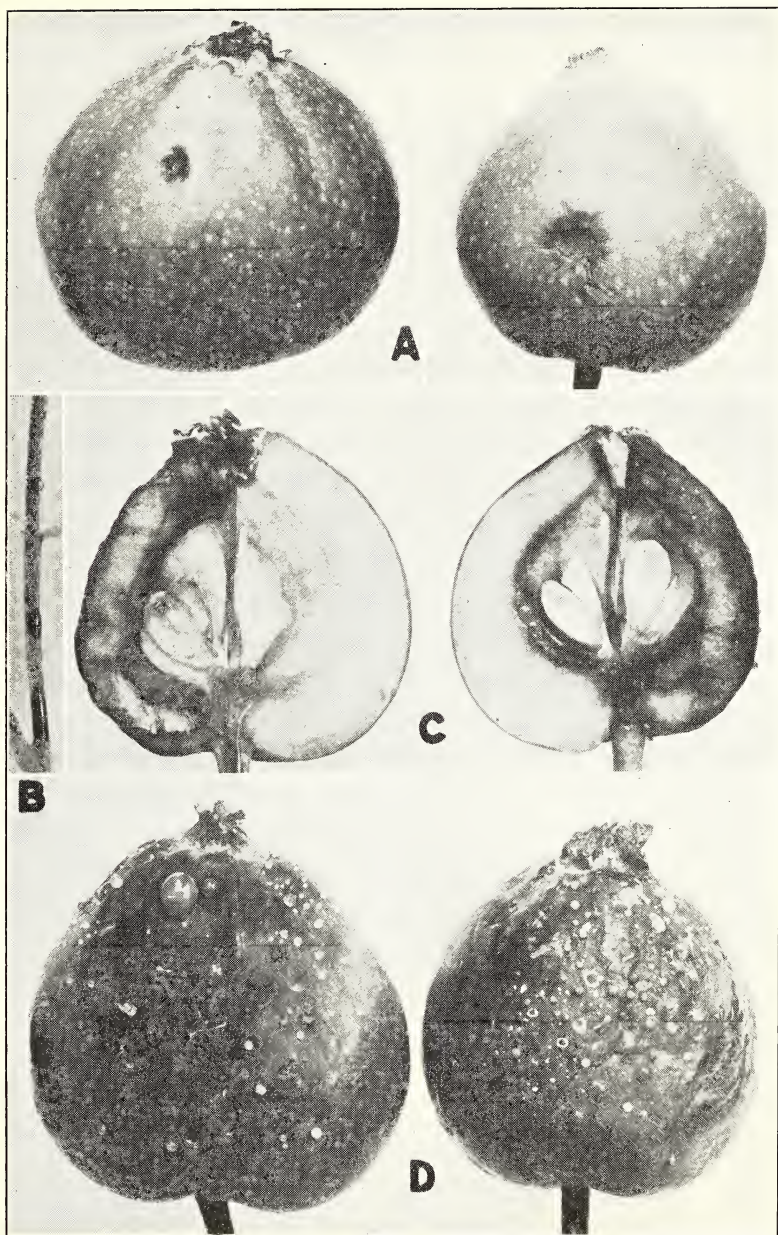


Fig. 2—Symptoms of apple fire blight on Transparent variety, Vincennes, June 11, 1926. A. Young apples showing small sunken fire blight lesions which were perhaps the result of infected wounds. B. Exudate on young tender twig. C. Young apples in longitudinal section showing internal effects of fire blight invasion. D. Fire blight exudate on young apples.

watersoaking of the tissues, with large, sticky drops of exudate on the skin (fig. 2). Some fruit infection was also found in the Jonathan variety. Mr. R. A. Simpson at Vincennes observed that much of the infection in the Jonathan variety occurred through a secondary late setting of blossoms and that bad cankers resulted from infection of the knife cut girdling wounds which had been made in young Transparent trees to stimulate earlier fruiting.

In connection with the fruit infection, it is of interest to note that laboratory inoculation tests made on mature Baldwin and Rome fruits showed that the fire blight bacteria will progress very rapidly throughout the vascular system of the fruit, without causing any discoloration of the flesh other than a faint browning of the veins.

Peculiar effects of fire blight infection were noted in a block of young Oldenburg trees in Knox County on July 22. Many half-grown fruits were shriveled, stunted and often prematurely colored due to spur cankers which had not killed the spur. Fire blight was very serious on the King variety near LaPorte, where very encouraging results were obtained by McCown in an attempt to control the disease by a weak Bordeaux spray applied at the time of full bloom.

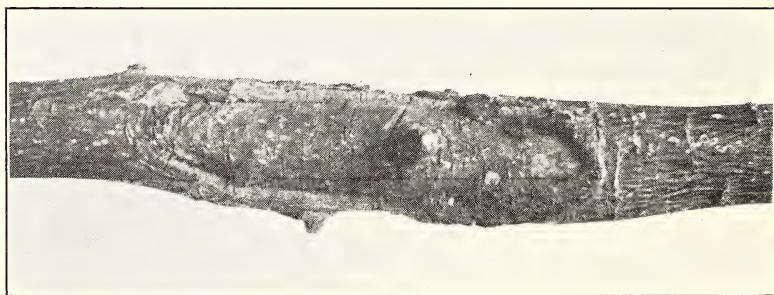


Fig. 3—The original apple bitter rot canker found by R. A. Simpson in southern Illinois in 1902 and reported to Dr. T. J. Burrill. (Burrill and Blair. Bitter rot of apples. Ill. Agr. Exp. Sta. Bul. 77:351-366. 1902. p. 355). Apparently it was an old fire blight canker secondarily invaded by the bitter rot fungus, spores of which are still present on it.

Reports from growers and observation of varietal susceptibility in commercial orchards and in the experimental orchard at Mitchell, where many varieties are represented, led to the following conclusions: The most susceptible varieties were Jonathan, King, Transparent, Willow, York, Maiden Blush, Esopus, Indian, and Detroit Red; the next less susceptible group would include Westfield, Northwestern, Northern Spy, and Wealthy. A still less susceptible or somewhat resistant group would include Baldwin, Stayman, King David, Golden Delicious, Benoni, Oldenburg, Genet, and Missouri Pippin. A group of resistant varieties, that is, those showing only slight infection, includes Rhode Island Greening, Red June, McIntosh, Tulpehocken, Thaler, Tetofsky, Akin, Grimes, Rome, Red Delicious, Winter Banana, Winesap, Clayton, Stark, Ortley, Carson,

and Williams Early Red. No infection was noted on Gano, Arkansas, Wolf River, Minkler, Salome, McMahon, Lawver, Kinnard, and Red Astrachan.

Bitter rot, caused by *Glomerella cingulata*, was very serious in September on the Grimes and Jonathan varieties in an orchard in Orange County where Bordeaux had not been used with the late codling moth sprays. Several hundred bushels of rotted fruit were hauled out of this orchard. The disease was first noted the last week of July in an orchard in Warrick County, where it has occurred annually with great severity. The high rainfall of August and September greatly favored this disease and late Bordeaux sprays proved very profitable in commercial orchards in the bitter rot region.

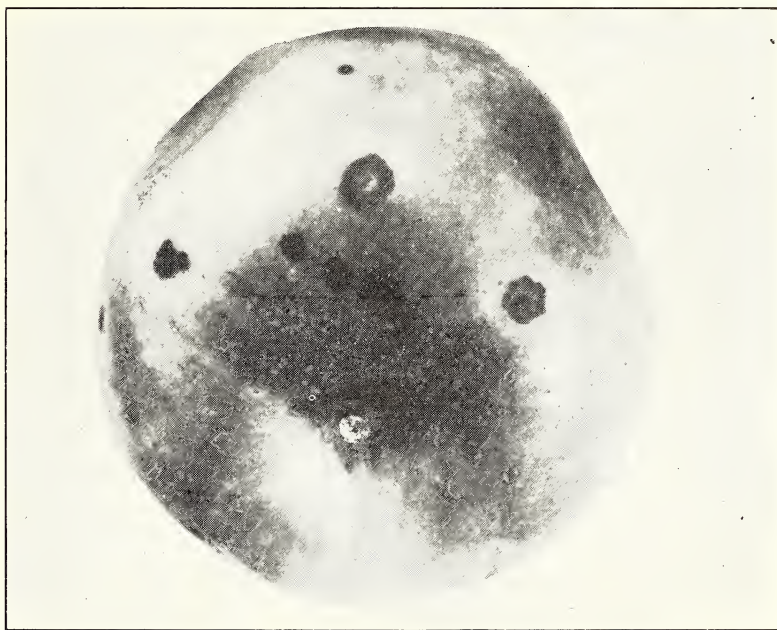


Fig. 4—Non-parasitic spotting of King David apple.

Rust (*Gymnosporangium juniperi-virginianae*) was rather abundant on the foliage of Jonathan and Rome in Orange County and a few calyx-end fruit lesions were found in the Oldenburg variety.

Black rot and frog-eye leaf spot, due to *Physalospora malorum*, were about as prevalent as usual. A few cases of calyx-end fruit infection were noted.

The rot caused by *Phytophthora cactorum* was found, September 14, on Grimes drops under the same trees at Lafayette where it occurred in previous years, and on September 22 some was found on Grimes drops in an orchard in Orange County.

The owner of an orchard in Marion County reports blister canker due to *Nummularia discreta* serious on Ben Davis, Maiden Blush, White Pippin, and Genet, present on Stark, Rome, Mammoth Black Twig, Jonathan, Clayton, and Transparent, and absent on York, Wolf River, Indian, Arkansas Black, and Winesap.

The wet weather was very favorable to sooty blotch (*Phyllachora pomigena*), which was rather abundant on Grimes in the orchard in Orange County where Bordeaux was not used in the late codling moth spray.

The non-parasitic stippen or bitter pit was found to a slight extent on Grimes and Rome fruit in Orange County, and a statewide outbreak of what appears to be a surface type of the same trouble occurred on King David fruit (fig. 4). Specimens of the latter were received from Knox, White, and DeKalb counties and cultural tests showed that no fungus was associated with the lesions. A similar spotting on this variety was noted in 1921. Measles, or brown bark spot, was found on Delicious and Winesap nursery stock in a nursery in Perry County, and was also found on Delicious in an orchard in Knox County. In Orange County a Grimes tree was apparently being killed by this disease. Much winter injury showed up in young plantings this spring.

Barley.—Mains found a very slight amount of ergot (*Claviceps purpurea*) and of leaf rust (*Puccinia simplex*). Leer made a special search for stem rust, but was unable to find any.

Bean.—Anthracnose, caused by *Colletotrichum lindemuthianum*, occurred to a limited extent in home gardens because of the abundant rain late in the season, but Kendrick found none in the canning crop in Grant County in August. He did find bacterial blight, caused by *Bacterium phaseoli*, very serious, and it was also serious in the canning crop in Hamilton County in August. The pod infection is very objectionable to the canners of such beans. Kendrick found, however, that mosaic was the limiting factor in the canning crop in Grant County and had caused a stunting of plants and a greatly reduced yield of pods. A few cases of Fusarium wilt were found in Marion and Grant counties.

Bacterial spot of Lima bean, caused by *Bact. vignae*, was noted in Marion County on July 16.

Beet.—Leaf spot, caused by *Cercospora beticola*, was serious in gardens.

Blackberry.—Leaf spot, caused by *Mycosphaerella rubi*, and orange rust (*Gymnoconia interstitialis*) were prevalent.

Buckwheat.—The leaf mold caused by *Ramularia anomala* occurred in experimental plots in October.

Cabbage.—Yellows, caused by *Fusarium conglutinans*, was not as serious as usual. Black rot, caused by *Bacterium campestre*, was found in Indianapolis market gardens in July.

Cantaloupe.—Bacterial wilt, caused by *Bacillus tracheiphilus*, and the mosaic disease were very prevalent in Vigo and Knox counties in July. Mosaic was also severe in Indianapolis market gardens. Leaf blight, caused by *Macrosporium cucumerinum*, was much less destructive than usual.

Celery.—The Goshen celery marshes were examined by Kendrick on Aug. 18. Early blight, caused by *Cercospora apii*, was present only to a limited extent, and no *Fusarium* yellows was noted. Late blight, caused by *Septoria apii*, was found very serious and was killing many of the leaves of the crop being harvested at that time. This disease was also serious near Lafayette in the fall.

Cherry.—Leaf spot, caused by *Coccomyces hiemalis*, was not nearly as destructive as usual. Powdery mildew (*Podosphaera oxycanthae*) was sent in from Newton County.

Clover.—Powdery mildew (*Erysiphe polygoni*) was rather general. Mains found it worst on native strains in his test plots at Lafayette. He found anthracnose, caused by *Gloeosporium caulivorum*, and bacterial spot, caused by *Bact. trifoliorum*, very serious in these plots, which contained strains of red clover from many sources. Anthracnose he found worst on French strains, somewhat less severe on the Altaswede and Italian strains, and least destructive on North American strains. The bacterial spot he found worst on foreign strains, and entirely absent on Alsike clover. Mosaic, accompanied by its necrotic effects, was very destructive in his plots. Rust (*Uromyces trifolii*) was found on Alsike clover in Hancock County.

Corn.—Trost reports the occurrence of bacterial wilt due to *Aplanobacter stewartii* and estimates a loss of 6 per cent due to Gibberella and *Fusarium* root and stalk rots, of 3.5 per cent due to Diplodia ear rot, and of 0.5 per cent due to smut (*Ustilago zeae*). Mains estimates a 0.5 per cent loss due to rust (*Puccinia sorghi*).

Cowpea.—Bacterial spot, caused by *Bacterium vignae*, was found serious in Knox County in June, but only a trace occurred in experimental plots at Lafayette. Single plant selections of seed from healthy and mosaic plants of a number of varieties (Early Red, Early Black, Whip-poorwill, Iron, Red Ripper, Arlington, Clay, Conch, Columbia, Groit, and the related species, Catjang) were planted on June 3. On June 21, Kendrick examined the seedlings and found all healthy except for five mosaic plants among the progeny of 34 from a mosaic plant of the Progressive White variety. On July 8, 21 of these 34 plants showed the disease and none was noted elsewhere. Later, however, the disease became epiphytotic and attacked practically all of the plants of all varieties and of the related species, Catjang. The typical symptoms were the conspicuous mottling and malformation of the leaves, but peculiar symptoms were exhibited in certain varieties. Necrotic mottling of the pods occurred as a mosaic symptom in Catjang and in the Arlington variety, and petiole twisting and necrosis in the Red Ripper variety.

Cucumber.—Mosaic was very destructive near Lafayette in July, and Kendrick found it serious in a field in Kosciusko County. Bacterial wilt, caused by *Bacillus tracheiphilus*, occurred rather commonly.

Currant.—Anthracnose (*Pseudopeziza ribis*) was noted at Lafayette in July.

Grape.—Downy mildew (*Plasmopara viticola*) was found in the northern part of the state and crown gall was sent in from Morgan County.

Kohlrabi.—Yellows, caused by *Fusarium conglutinans*, was found at Lafayette (fig. 5).



Fig. 5—*Fusarium* yellows of kohlrabi. One sided yellowing and curvature of the leaf and bare stalk from which leaves have dropped.

Oats.—Stem rust (*Puccinia graminis*) caused a loss, according to Leer, of about one per cent, and crown rust (*P. coronata*) was reported serious in Starke County. Halo blight, caused by *Bact. coronafaciens*, was found in Hancock and Tippecanoe counties.

Onion.—Smudge (*Colletotrichum circinans*) was prevalent on white onions in Fulton and Whitley counties. In Marshall County, Kendrick found seed stalk lesions due apparently to *Macrosporium parasiticum*, which prevented the seed heads from maturing properly. Federal inspectors reported neck rot in cars from Marshall, Kosciusko, Whitley, Noble, and Steuben counties. Mr. Lyle, federal inspector at Warsaw, reported bacterial soft rot very prevalent owing to the wet fall weather.

Examination of yellow and red onions in a storage house in Kosciusko County in March, 1927, showed the presence of considerable basal

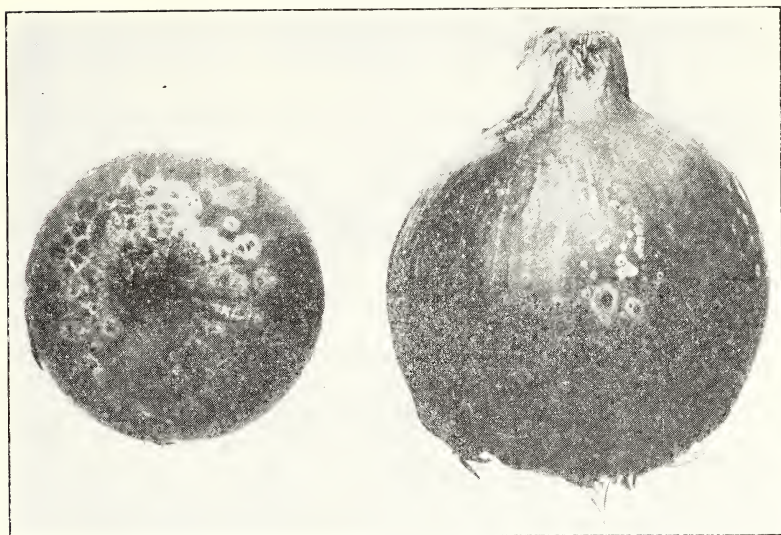


Fig. 6.—Silver spot on the dry outer scale of yellow onions, caused by a species of *Penicillium*.

end *Botrytis* rot, and of a bacterial soft rot of the outer scales. Also there was much of the blackened blotch lesions (cause unknown) and the bleached silver spot (*Penicillium*) on the dry outer scale (fig. 6), both of which render the onions unsightly and lower the sale price.

Pea.—In a survey of canning crop fields in Miami and Wabash counties on June 7, Kendrick found *Fusarium* wilt⁶ responsible for a loss estimated at five per cent. He also found a scattering infection of *Rhizoctonia* stem lesions and in one field a small area of bacterial spot (*Bact. pisi*) infection. On June 30, he found bacterial spot very destructive in the canning crop in Tipton County. Injury to the foliage was severe and the pods were very abundantly spotted (fig. 7). Pod spot caused by *Ascochyta pisi* was found in a garden at Lafayette.

⁶ Linford, Maurice B. A wilt disease of peas in Wisconsin. Abs. in Phytopath. 16:75. 1926.

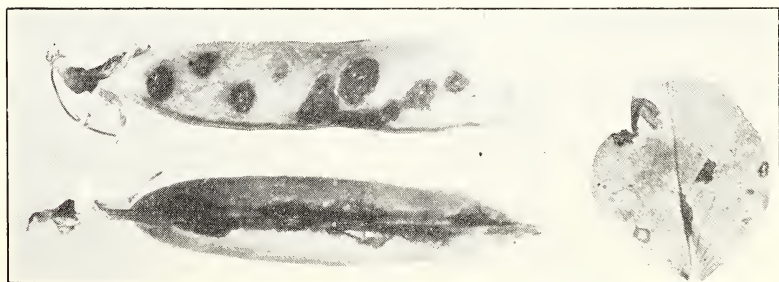


Fig. 7.—Bacterial spot of pea.

Peach.—In April, leaf curl, caused by *Exoascus deformans*, was very serious in Knox, Sullivan, and Greene counties in orchards not properly sprayed. In one orchard, the Eads and Elberta varieties were nearly defoliated, while the Krummel variety escaped infection. Burkholder and McCown found fruit infection in Sullivan County. Scab, caused by

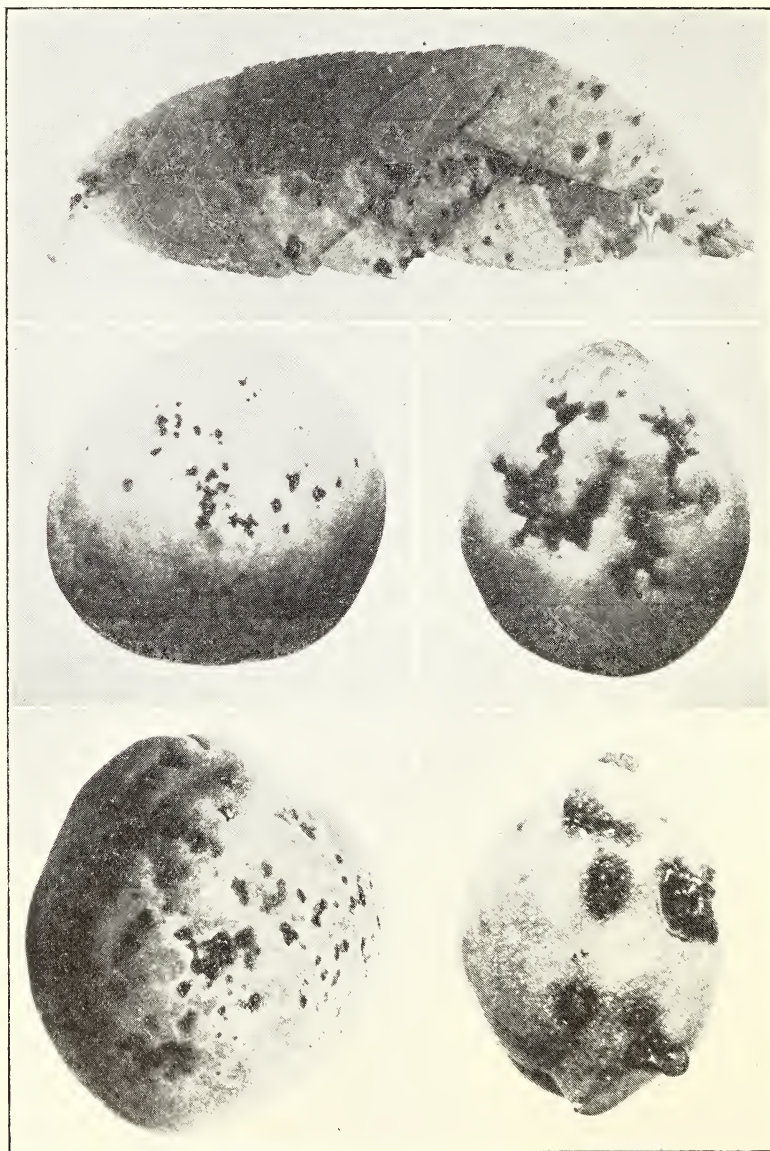


Fig. 8.—Bacterial spot of peach, caused by *Bacterium pruni*.

Cladosporium carpophilum, was reported from five counties and fruit infection occurred in Fayette County. Bacterial spot (fig. 8) caused by *Bacterium pruni* was not destructive until late in the season when it not only caused much defoliation but also blemished the fruit. Burkholder found leaf infection as early as June 3 in Knox, Daviess, and Martin counties, and B. A. Porter found fruit lesions in Knox County on June 12. Crown gall was sent in from Monroe County.

Pierce found discharging apothecia of the brown rot fungus (*Sclerotinia fructicola*) under the seedling trees in an orchard in Knox County, on April 21. None were found under the other trees, a circumstance which further strengthens the case against the seedling peach tree as a brown rot menace. Heavy rains in August favored brown rot and considerable losses resulted, especially in late varieties. Burkholder found much brown rot in the Redbird variety in Jackson County, and following hail injury to the fruit in Sullivan and Greene counties. Rhizopus rot was reported in five cars from Knox and Posey counties by the federal inspection service.

Pear.—Fire blight was very serious. Leaf spot caused by *Mycosphaerella sentina*, the rot caused by *Phytophthora cactorum*, and sooty blotch (*Phyllachora pomigena*) occurred near Lafayette in the fall.

Pepper.—Mosaic occurred very generally in market gardens.

Plum.—Black knot was sent in from Huntington County and brown rot was reported from Marion County.

Potato.—Leaf roll remains the most serious disease in the late crop (Rurals) and mosaic is common in the early crop. Field plots planted with seed tubers previously tested for disease in the greenhouse showed that leaf roll spreads much more generally than mosaic. Fusarium wilt occurred in Jasper County, and scab was widespread in its occurrence. Following the heavy rains in August and September, bacterial soft rot was destructive in Marion County and considerable tuber infection of late blight, caused by *Phytophthora infestans*, occurred in LaPorte County. This is the first authentic record for this disease in the state since this series of disease survey reports was begun (1919).

Pumpkin.—Downy mildew (*Peronoplasmopara cubensis*), powdery mildew (*Erysiphe cichoracearum*), and a Cercospora leaf spot were found on field pumpkins near Lafayette in October.

Radish.—White rust (*Cystopus candidus*) and black root, caused by *Aphanomyces raphani*,¹ were found at Lafayette.

Rape.—Leaf infection by the black rot organism, *Bact. campestre*, was found in Hancock County in June.

Raspberry.—Anthracnose (*Plectodiscella veneta*) was serious, as usual, and was reported from six counties. Leaf spot caused by

¹ Kendrick, James B. Radish black-root caused by *Aphanomyces raphani* n. sp. Abs. in Phytopath. 17:43. 1927. Also: The black-root disease of radish. Purdue Univ. Agr. Exp. Sta. Bul. 311:1-32. 1927.

Mycosphaerella rubina was found at Lafayette. Crown gall was sent in from Wabash County and was found by Dietz in Elkhart County. Leaf curl and mild mosaic were noted on black raspberry near Lafayette.

Rye.—Mains noted anthracnose (*Colletotrichum cereale*), ergot, scab caused by *Gibberella saubinetii*, powdery mildew and leaf rust. Leer made a special search for stem rust and found none.

Sorghum.—Kendrick found bacterial spot,⁸ caused by *Bact. holci*, on sorghum and sudan grass in experimental plots at Lafayette.

Soybean.—Prof. F. E. Robbins found mosaic rather serious in a field of the Midwest variety in Hamilton County. Bacterial blight caused by *Bact. glycineum* was noted or reported in Fulton, Montgomery, Parke, and Warrick counties. Brown spot,⁹ caused by *Septoria glycines*, was found in Montgomery and Parke counties.

Spinach.—Brown found downy mildew (*Peronospora effusa*) at Lafayette in May.

Squash.—Mosaic and a bacterial leaf spot were found near Terre Haute Aug. 9.

Strawberry.—Leaf spot caused by *Mycosphaerella fragariae* was generally prevalent and the virus disease (mosaic or yellows) was reported from Knox and Greene counties.

Sweet potato.—There was an unprecedented epiphytotic of the *Fusarium* stem rot in Vigo, Knox, and Gibson counties in June, and the losses were such as to cause much concern among the growers. Black rot, caused by *Ceratosomella fimbriata*, was found in storage houses in Gibson County, causing very heavy losses.

Tobacco.—Angular leaf spot, caused by *Bact. angulatum*, was found in Orange County.

Tomato.—*Septoria* leaf spot was not as destructive as in 1925 despite the frequent and heavy rains. In general the disease appeared too late in the season to cause heavy losses. Kendrick found it serious in certain fields near Marion on Aug. 10, and on Aug. 16 it was found serious in one field near Indianapolis used for tomatoes the preceding year. Late in the season the disease was found, usually in small areas, in fields in Madison, Marion and Hancock counties. It was found in July in a greenhouse crop and a staked garden plot where overhead irrigation was being employed. There was one badly infected field in the Paoli district and on Aug. 12, examination of this field, which was planted in part with homegrown plants, showed that the disease was much worse in the part of the field set with the home-grown plants and that it was also present in the plant-bed from which these

⁸ Kendrick, James B. Holcus bacterial spot of *Zea mays* and *Holcus* species. Iowa Agr. Exp. Sta. Res. Bul. 100:303-331. 1926.

⁹ Wolf, Frederick A. and Lehman, S. G. Brown spot disease of soybean. Jour. Agr. Res. 33:365-374. 1926.

plants were taken. This plant-bed, which, incidentally, had been used for tomatoes the previous year, was without doubt responsible for the field epiphytotic, since the transplants used in the other part of the field were taken from the canning company plant-beds which were proved to be free from this disease by its failure to appear in an experimental field set with plants from these beds.

Early blight, caused by *Alternaria solani*, was the most serious foliage disease of the season. It was found in nearly all fields examined late in the season and caused much defoliation. In an experimental field at Paoli which was under frequent observation early blight was first observed on July 26, on the older leaves and in the form of a collar rot of a few scattered plants. By Aug. 12 the disease was prevalent throughout the field and by the end of the month had caused very severe premature defoliation. There was also some spotting of the fruit due to this fungus. Dusting tests¹⁰ in this field showed that a copper lime dust containing 25 per cent dehydrated copper sulphate visibly retarded the progress of early blight and increased the yield by three to four tons per acre. Since early blight was the only serious foliage disease in this field, it seems safe to assume that the increase in yield in the dusted plots was due to the partial control of this disease. Similar results were obtained in tests at Greenfield.

Fusarium wilt was of major importance early in the season and was recorded from 12 counties. Badly diseased fields were found in Marion and Vigo counties. The serious cases could usually be traced to the use of southern-grown plants, or soil infestation resulting therefrom, but cases occurred in which a few diseased plants were scattered through a field in districts, such as the region around Paoli, where, as far as is known, no southern-grown plants have been used.

Mosaic occurred rather generally in the canning crop late in the season, and the double-virus or streak type was not uncommon in the field. On Aug. 25, Kendrick found the double-virus mosaic rather severe in the acreage around French Lick and a month later much of it was found in our experimental field at Paoli. The double-virus mosaic ruined a crop in a new greenhouse near Indianapolis which had been built over an old potato patch and in which volunteer potato plants had repeatedly pushed up among the tomatoes.¹¹

Field surveys in nine counties showed that bacterial spot, caused by *Bact. vesicatorium*, was more prevalent than it had been since 1919. It was observed the middle of July in southern and central Indiana and was conspicuous for about a month. Thus the peak of the epiphytotic occurred rather early in the season and the first fruits set were badly spotted. There was an abundance of peduncle, pedicel and calyx spotting (fig. 9) as well as foliage infection. The infection on peduncles and pedicels seemed to be much heavier on the upper surfaces. The rather large calyx lesions were distinguishable from the smaller, more numerous, non-parasitic, necrotic spots, crowded toward the apical end

¹⁰ Gardner, Max W., Kendrick, James B., and Cochran, L. C. Dusting tests for the control of tomato diseases, 1926. Trans. Ind. State Hort. Soc. 1926:75-83. 1927.

¹¹ Gardner, Max W. and Kendrick, James B. Potatoes, a virus disease menace to tomatoes. Hoosier Hort. 9:5-8. 1927.

of each calyx lobe. The circular, whitish, "birds-eye" type of fruit lesion was found very generally and, in early stages, these lesions yielded a bacterial exudate in water mounts. Considerable infection occurred in the two fields where dusting tests were in progress and there was evidence that the copper lime dusts afforded some measure of control.

Leaf mold, caused by *Cladosporium fulvum*, was serious in green-houses. Gregory found cases in which growers failed to control the disease by spraying with soda Bordeaux. One grower at Logansport has tried dusting with copper lime with very satisfactory results.



Fig. 9—Tomato bacterial spot lesions. A. Stem. B. Peduncle and pedicels, enlarged X2.

Owing to the heavy rainfall late in the season, buckeye rot, caused by *Phytophthora terrestris*, occurred for the first time, to our knowledge, as a serious factor in canning crop fields. Kendrick found this disease late in August in 12 fields in Madison and Hancock counties and a month later in Orange County. The disease was not in any sense a ripe rot. The fungus attacked the green fruits of all ages and caused a total loss in the badly infested areas, which were usually in the low lying spots in the fields. In one field in Hancock County over 50 per cent of the fruits were found infected on Aug. 23 and a month later there were practically no fruits to be found. The disease had made a clean sweep. The copper lime dust did not check this disease in our experimental fields.

Rhizoctonia soil rot was found in Marion County on Aug. 16. Anthracnose (*Gloeosporium phomoides*) was found late in the season in Madison, Hancock and Marion counties. In a wet season such as this it was not surprising to find much rotting of the fruit due to growth-crack invasion by various organisms.

Blossom-end rot (non-parasitic) was found on Aug. 5 in Tipton, Howard, and Madison counties and was rather prevalent on the first

fruit set. On the black soil of Tipton and Howard counties, A. H. Watson found a non-parasitic necrotic spotting and blighting of the older leaves apparently associated with potash shortage in the soil.

Too heavy dusting of the young growing tips of the plants in the first sulphur applications in our dusting tests (*loc. cit.*) caused a peculiar injury to the tips as a result of which the young leaves became thickened, rolled, torn and greatly malformed, the apex ceased growth, and the plants were visibly stunted, though lateral shoots soon developed to replace the injured leader. There was no visible burning or necrosis of the injured leaves. This type of injury has been reproduced in greenhouse tests with pure sulphur.

Vetch.—On June 12, a circular leaf spot was found rather abundant in definite centers of infection in a vetch cover crop in an apple orchard in Knox County. No fungus fructification could be found on these lesions but tissue plantings yielded a fungus forming small black sclerotia in culture.

Watermelon.—Fusarium wilt was reported from four counties.

Wheat.—Stem rust was more prevalent than usual and Mains and Leer estimate the loss at 0.5 per cent. Mains estimates the loss due to leaf rust at 5 per cent. Gregory found less loose smut than usual, but found bunt (*Tilletia laevis*) more prevalent than usual and attributes to it a loss of 4 per cent.

Trees and Ornamentals.—The virus disease or yellows of aster was found serious in a commercial planting in Marion County. A mosaic disease was noted on *Digitalis* (Giant Shirley). Geranium bacterial spot was found by Dietz in greenhouses. The Verticillium wilt¹² of hard maples was found at Lafayette and is very prevalent on Norway maples in Elwood, where it has caused much concern among the citizens of that town. The causal fungus has been isolated from specimens sent in from Elwood. Anthracnose (*Gloeosporium apocryptum*) was found on hard maple near Lafayette on June 13. Iris leaf-spot caused by *Didymellina iridis* was common in gardens. On June grass, smut (*Ustilago striaeformis*) and leaf spot, caused by *Scolecotrichum graminis*, were found in June. Mosaic was noted on Nicotiana. The canker caused by *Dothichiza populea* was found on Lombardy poplar. Powdery mildew (*Erysiphe cichoracearum*) occurred on Phlox. Dietz found snow mold (*Scorias spongiosa*) on white pine needles and twigs in Indianapolis. Fire blight occurred on quince, and black rot of the fruit, caused by *Physalospora malorum*, was sent in from Knox County. Leaf spot of red bud caused by *Cercospora chionca* was common near Lafayette in the fall. Powdery mildew (*Sphaerotheca pannosa*) occurred on roses and Dietz reported black spot, due to *Diplocarpon rosae*, severe in greenhouses. Anthracnose (*Gnomonia veneta*) was noted on sycamore. An angular leaf spot, due probably to *Cercospora atricincta*, was found on zinnia.

¹² Gravatt, G. F. Maple wilt. U. S. Dept. Agr. Cir. 382:1-13. 1926.

SUMMARY

The diseases of outstanding importance were as follows: apple fire blight and bitter rot; bean mosaic and bacterial blight; cantaloupe mosaic and bacterial wilt; clover mosaic; corn root, stalk, and ear rots; pea Fusarium wilt and bacterial spot; peach leaf curl, bacterial spot, and brown rot; potato virus diseases; sweet potato black rot and Fusarium stem rot; tomato bacterial spot, early blight, mosaic and streak, and buckeye rot; wheat leaf rust; maple wilt.

The diseases or parasitic organisms not previously reported for the state in the Academy Proceedings include: Verticillium wilt of maple; pea fusarium wilt; pear rot—*Phytophthora cactorum*; white pine snow mold—*Scorias spongiosa*; pumpkin—*Peronoplasmopara cubensis* and *Erysiphe cichoracearum*; rape black rot—*Bact. campestre*; sorghum and sudan grass—*Bact. holci*; soybean brown spot—*Septoria glycines*; vetch leaf spot; zinnia leaf spot—*Cercospora atricincta*.

Other observations of interest were vascular penetration of apple fruit tissue by fire blight bacteria in laboratory inoculation tests, varietal susceptibility of apples to fire blight, seed transmission of cowpea mosaic by the Progressive White variety, the seedling peach tree as a brown rot menace, occurrence of *Phytophthora infestans* in potato tubers, renewed prevalence of tomato bacterial spot and buckeye rot (*Phytophthora*) of green tomato fruits, and sulphur dust injury to tomatoes.

MYCORRHIZA BEARING SPECIES IN THE VICINITY
OF LAFAYETTE, INDIANA.¹

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Accounts of mycorrhiza investigations up to the present time have been reviewed by Rayner (1926, 1927) and Waksman (1927). The distribution and extent of development of mycorrhiza in plants has been recorded more completely for native species in Europe than in America. In the United States the investigations of McDougall (1914, 1916, 1927), Lohman (1926), Jones (1924), and Coville (1910) indicate that mycorrhiza-producing fungi are widely distributed. While the European workers: Gallaud (1905), Janse (1897), Magrou (1921, 1925, 1927), Bernard (1910, 1911), Demeter (1923), Bjorenheim (1904), Constantin (1924), Magnus (1901), Frank (1885, 1887, 1888, 1891), Melin (1922, 1925), Melin and Helleberg (1925), Peklo (1909), Reyronel (1921, 1923), Nicholas (1924), Woronin (1885), Wolff (1926), Stahl (1900), Tubeuf (1903), Weyland (1912), Rayner (1915), McLennan (1926), and Ternetz (1904) have arrived at conclusions regarding the physiologic effects of mycorrhiza-producing fungi on roots, the evidence has often been so conflicting or insufficient as to demand further investigation. In many cases this was due to a lack of knowledge concerning the identity of the fungi or the methods of isolation. According to a classification of symbiotic phenomenon set up by McDougall (1918), the works of McLennan (1926) on the fungus of *Lolium temulentum*, and Rayner (1915, 1922) on that of *Calluna vulgaris* indicate that reciprocal, nutritive, conjunctive symbiosis occurred. The fungi were not only found in parts other than the roots but were also thought to be seed transmitted. A similar obligate symbiosis observed by Ramsbottom (1924), Kusano (1911), Constantin (1926), Burgeff (1909), and Bernard (1911) between a fungus and the bulbs of orchids during germination and early growth stages, has been found by Knudson (1924, 1925) to be due to a carbohydrate transition, possible to be produced by fungi other than the one previously supposed specific. Normal germination and growth was obtained by adding the proper carbohydrates without the fungus. Under natural conditions, however, it is apparent that these plants depend upon fungus activities. A possible increased nitrogen obtaining power of *Vaccinium corymbosum* due to the action of the ever-present root fungus has been suggested by Coville (1910), while in other members of the *Ericaceae* the fungus has been considered active in a similar capacity by Ternetz (1904, 1907) and in an entirely different manner by Christoph (1921) and Dufrenoy (1917). Jones (1924) found some

¹ Contribution from the Department of Botany, Purdue University Agricultural Experiment Station, Lafayette, Indiana.

evidence that mycorrhizas formed in the roots of leguminous plants were detrimental.

The fungi producing mycorrhizas in roots of forest trees have been considered by McDougall (1922, 1927) as antagonistic nutritive conjunctive symbionts acting as parasites. A similar parasitic nature of the mycorrhizas of *Alnus* and *Quercus* in Japan has been described by Masui (1926). As a result of extensive cultural experiments with European forest mycorrhiza-producing fungi, Melin (1925) concluded that the hosts or higher plants derived some benefit. It is evident that the physiological processes in roots bearing mycorrhiza is not completely understood.

Types of mycorrhiza. The term "mycorrhiza" has been used to designate the condition of a fungus-root system in which the fungus forms a specialized structure either around or upon the root surface, between the cells (inter-cellular), or within the cells (intra-cellular). Used by Frank (1885) to describe the mass of filamentous strands surrounding the tips and passing between the outer cell layers of forest tree roots, it has since been applied to the intra-cellular structures often found in the same roots and wrongly to the entire fungus-root or to the fungus itself, regardless of the structure formed.

The division of mycorrhizas into two general types has been based upon the position assumed by the fungus with respect to the root cells. The term "ectotrophic" has been used to describe the type forming external mantles and intercellular structures, while those forming intra-cellular structures have been termed "endotrophic." It has been observed by Masui (1926), Lohman (1926) and McDougall (1927) that some fungi produce mycorrhizas having both an intercellular and an intracellular structure. First described in *Tilia americana* as an heterotrophic form by McDougall (1914), these dual forms have since been termed "ecto-endotrophic." Fungi producing the respective forms are thus called endophytes, ectophytes or ecto-endophytes. While they have served to distinguish known forms, it is evident that the earlier terminology did not always describe the structures produced.

The identity of fungi producing mycorrhizas has been more often definitely determined in the ectotrophic forms. Kauffman (1921) identified *Amanitopsis*; McDougall (1914, 1916), *Russula*, *Boletus*, *Scleroderma*, and *Laccaria*; and Masui (1926), *Cantharellus*. Endophytes have been found by Ternetz (1907) as *Phoma*; Kusano (1911), *Armillaria*; Bernard (1911) and Demeter (1923), *Rhizoctonia*, and Pennington (1908), *Boletus* and *Tricholoma*.

Conditions for development. The production of mycorrhizas in various plants has been found dependent on the environment of both root and fungus. Growing roots and the presence of the proper fungus have been given by McDougall (1916) as essential requirements. It is evident, however, that these may be in turn modified by additional factors. Paulson (1924) considered moisture essential and found the most extensive development of tree mycorrhizas in the lower layers of the moss carpet, apparently due to a chemotoxic action of decay. While

mycorrhizas of the deciduous trees have been found in greater numbers when roots were growing in leafmold or decaying organic material, McDougall (1927) reported mycorrhizas of *Pinus flexilis* in soil composed largely of volcanic cinders. Endotrophic forms have been found by Rayner (1915) and Coville (1910) in acid soils. Lohman (1926) found mycorrhiza-like fungi more common and developing better in soils with a pH value below 6.5, although many occurred in neutral and alkaline conditions. The wide distribution of mycorrhiza in plants makes it increasingly evident that the present knowledge of physiology, length of life, and relative development of the fungi producing them under different soil conditions is insufficient to draw conclusions regarding the degree of parasitism.

Local Survey. A study of plants known in the other regions to possess mycorrhizal root structures was begun in the vicinity of Lafayette in 1925 and continued as a root-fungus survey of all possible native plants and trees in 1926 and 1927. The present paper is a list of the species bearing mycorrhizas in this locality, including a detailed description of forms not previously described and a summary of observations concerning the apparent nature of the fungus-root association. While the identification of fungi producing the mycorrhizas here studied has not been undertaken, it is hoped that the records of distribution, types, and extent of formation may serve as a basis for further physiological investigations.

The region included in this survey lies between West Lafayette and Battle Ground, Indiana, extending one mile west from the Wabash River. A series of steep wooded slopes, moist lowlands and sod-covered, pastured woods is included within this area. The predominating soil types are Miami silt loam and Wabash sandy loam with occasional narrow strips of fine sandy loam near the creeks. While these soil types are distinct in most cases many mixtures with gravel out-crops on the steeper slopes and sandy deposits near creeks are found. Soils of the wooded slopes are mostly covered by a heavy leaf-fall accumulation.

Methods of Collection and Identification. In a study of this type, accuracy in identifying the source of rootlets from a large number of species and the later determination of types of mycorrhiza from collected material was found to require special precautions. A definite method of collection was followed. Roots found upon examination with a hand lens to possess external signs of fungus association were traced to their respective plants before removal. If a field identification of the higher plants was not possible, collections of these were made for later identification.

Rootlets removed from the known plants were placed in the field into each of two fixing solutions and a solution of formalin. Formalin acetic alcohol and Schaffner's chromo-acetic fixing solutions were used. Formalin solution (1 part commercial formalin in 14.5 parts distilled water) was used for preservation of material for immediate free-hand sectioning. It was found convenient to carry about 50 vials of the three reagents, each supplied with a blank label in a portable typewriter carry-

ing case. By giving each vial and plant collection a corresponding number and placing the plant species name on each vial it was not found necessary, after recording the soil conditions and extent of development, to duplicate the results of later examination in the field records.

Fagus grandifolia Ehr. Roots collected in November 1926, April, May and from July to October 1927 have shown the presence of three distinct forms, distinguished by the character of mantle, and extent of extrance into roots.

A brown, waxy, smooth surfaced mantle and extreme hyper-enlargement of rootlets, together with the absence of filamentous strands, characterizes the least common form found in this vicinity. (Fig. 1.) Rootlets in a hard clay soil have been observed to possess this form, while in moist leafmold the other forms have been found upon each collection.

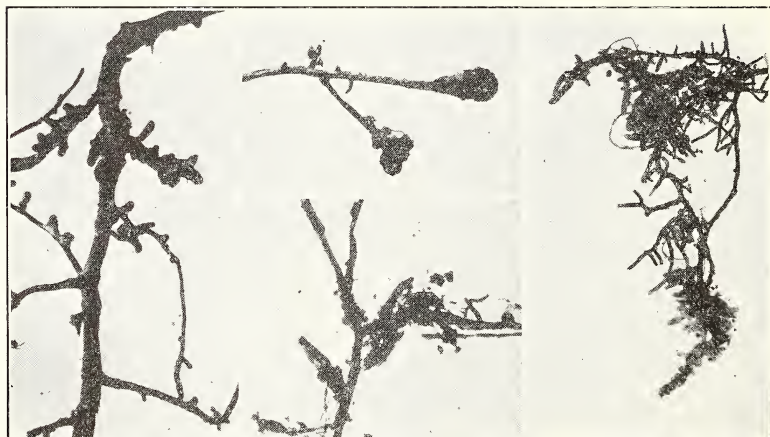


Fig. 1—Mycorrhizas of beech (*Fagus grandifolia*). Left. Form 1, producing a brown, waxy, compact mantle. Terminal root-tip of form 1, showing extreme enlargement, containing short laterals within same mantle. Form 2. Yellowish mantle, showing coarse filamentous strands attached. Form 3. White mantle, numerous fine filaments produce a woolly surface.

The second form found has a bright yellow mantle from which many stiff rhizomorph-like strands arise. (Fig. 1.) It has been observed most frequently on roots growing in rotting wood, frequently in dead stumps of oak.

Most widely distributed in this region is the third form, which produces a white, finely filamentous mantle. (Fig. 1.) It has been collected from both a moist and dry situation but develops to greatest extent in moist leafmold. Of these three forms, the first seems in some cases to live for two years, especially on terminal, strongly growing roots. While this form seems to produce a small amount of intercellular growth, the root tips were found to have several laterals which apparently turned forward into the same enclosing mantle. Paulson

(1924) described a brown, waxy form on *Fagus sylvatica* in England but, since this character is not mentioned, it is probably produced by a different fungus.

Populus tremuloides Marsh. An ectotrophic form producing thick, white mantles and intercellular growth closely resembling that found in white oak was collected in this section. While identical in all characters to the form on *P. deltoides* it has not been found on all trees examined. McDougall and Jacobs (1927) described a form closely resembling this one, which was collected in a western region where it occurred only in rotten wood. The lack of extensive mycorrhiza development on this plant cannot be attributed to lack of moisture in the situations most commonly found. It has been observed, however, that it occurs in sandy wash soil which is seldom permanently covered by leafmold.

Populus deltoides Marsh. Densely filamentous mantles were found during July and August, 1927, on trees growing in a wet, sandy soil near the mouth of a creek. The absence of leafmold on the surface did not seem to hinder development. Lohman (1926) described both an ectotrophic and an endotrophic form for this species but did not mention the mantle color of the former. Numerous dead roots and mantles found among the living ones collected in late summer indicates an annual development of this form. It has been found in this section only in a continually moist situation.

Carya cordiformis (Wang.) K. Koch. A white ectotrophic form was collected August 1, 1926, and repeatedly until December 1 the same year. Sections made during the fall and from material collected in April the following year showed groups of fungous strands passing beyond the first layer of slightly radially elongated cells and in contact with the first cortical layer. It was observed during intervals of collecting that mantles of this form became completely developed within a period of 10-12 days and did not become larger during the remainder of the season. Aside from the lack of decidedly radially elongated cells of the first layer, this form agrees with the form 3 described by McDougall (1914) on *C. ovata*. In this section it was found on all roots growing in and several inches below moist leafmold.

Carya ovata (Mill.) K. Koch. An ectotrophic form producing yellow mantles was found in late September, 1927. In removing roots from loose soil it was observed that many soil particles adhered to the mantle surface. The filamentous character of the mantle resembles the form 1 described on this species by McDougall (1914). While it has been collected in this locality from trees growing in sod and in all excepting very dry conditions, the mycorrhizas always occurred in clumps of decomposing grass roots near the surface and occasionally in portions of dead roots deeper in the soil. From a collection made on May 10, 1927, living roots having fully developed mantles apparently formed in the previous growing season were obtained. Since in the two attempts to collect during late June only brown mantles on dead roots were available, this form is probably always annual.

Tilia americana L. Dense, smooth, gray mantles were found in groups whenever they had access to surface accumulation of moist

organic matter. In 1927 they were found in leafmold above dry gravel subsoil from late July until October. This was apparently the heterotrophic form 6 described by McDougall (1914) as having, in addition to a mantle and intercellular growth, occasional intracellular strands. Since roots collected August 15 did not show the latter development, it is probable that it occurs only late in the season or under adverse conditions. Living mantle-covered roots were not found during June.

Cercis canadensis L. Two types of mycorrhiza development were found. The first, a yellow, compact mantle covering entire root tips was found in moist leafmold in two collections. In the second type a mantle-like pseudoparenchymatous mass of yellow mycelium was found tightly attached to the roots 4-5 millimeters back from the tips. Occurring as a modified mantle, it was found in some cases passing entirely around and in others compactly appressed to one side or partially enclosing the root. This condition was found most commonly in the more moist soils. While it is apparently due to the rapid root growth at the time the mantles are being formed, this plant is known to show a less rapid root development than other forest trees. The reasons, however, for the affinity of the ectotrophic forms for root tips are not clearly

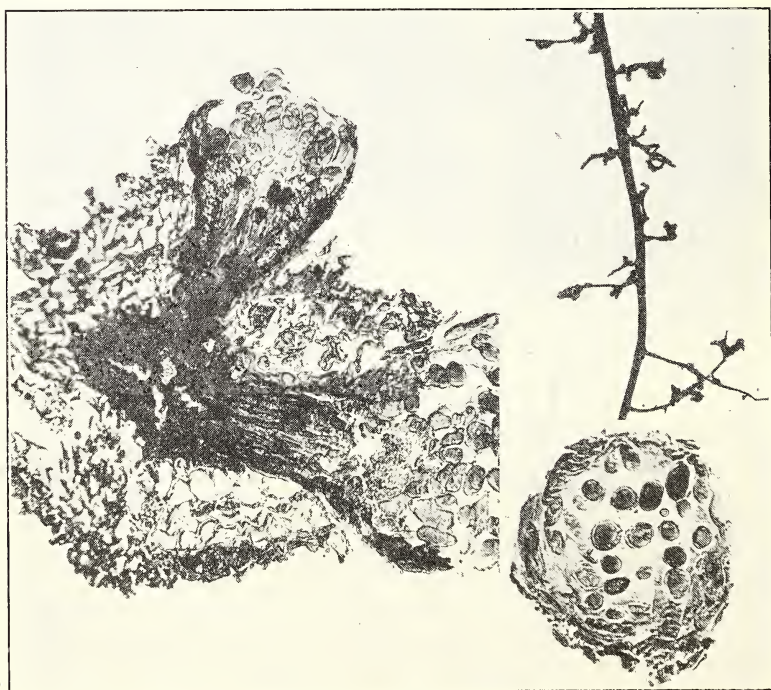


Fig. 2—The mycorrhiza of ironwood (*Ostrya virginiana*). Left. Transverse section of root near tip, showing intercellular development of fungus in growing points of laterals. Transverse section of short lateral, showing separation of cells by groups of fungous strands. Roots fresh from soil, showing profuse branching near tips.

understood, and it is probable that the condition here observed was due to a difference in the rate of development of the fungus or to a toxic root exudation at the tips.

Ostrya virginiana (Mill.) Will. The ectotrophic form occurring in this vicinity was found upon sectioning and staining to bear a peculiar relation to root laterals. The white mantles usually found in late July to produce only slight intercellular growth were found in roots collected October 7 and 8 to extend between the outer cell layers of short laterals. (Fig. 2.) Entry occurred at the tips. These were apparently produced on roots having the early formed mantles. Rapid entry of the filamentous strands between the cells inhibited all further growth of laterals, while in some roots disintegration had resulted. Lohman (1926) reports a thick mantled ectotroph for this species and in one collection an endotroph. This mycorrhiza has been found under all soil and moisture conditions favorable for growth of the plant.

Carpinus caroliniana Walt. The ectotrophic smooth white or gray mantle and compact structure of strand groups passing from the mantle surface into the leafmold, distinguish the most common form on this species from another which develops uniformly on the surface. The first has been found abundant in leafmold. A collection made September 20 and again from the same tree on October 1 and 2, 1927, showed the first form only. The second form has been observed on roots growing deep in the edge of a moist clay bank. An ectotrophic form was found on this species by McDougall (1914).

Erythronium albidum. Nutt. The root system of this species was found divided into a many-beaded structure resembling the endotropic mycorrhizal roots of *Acer rubrum*. Free-hand sections from roots taken in July, 1927, showed slightly clouded, gray glomerulus strands in cells of the first cortical layer and direct intercellular connections with a dark brown mycelium on the root surface. In a second group of roots collected, this same type of structure was found in one case, a dark colored root tip Lohman (1926) described a phycomycetoid endotroph in this species from roots collected in April.

Rumex Acetosella L. Roots taken during the summer of 1927 were found to contain intracellular strands terminating in a knob-like structure. Entered cells were not darkened. Since only free-hand sections of this form were made, the nature of the attachment to external mycelium is not known. It is apparently a true endotroph growing directly from the soil and producing thick hyphae which become brownish in color after entering roots.

Adiantum Pedatum. Two collections taken in May, 1927, showed an endotrophic form in all shortened lateral root tips. These were from a shaded, moist location, apparently most favorable for the plants. Root cells entered by the fungus were in all cases dark in color and entire roots were often found dead. In describing an endotrophic form in this species, Lohman (1926) concludes that the distorted, darkened thick root branches apparently associated with entrance by the fungus indicates true parasitism. As in case of many ferns, the limiting of plants to moist situations causes a continual infection by the endophyte.

Acer rubrum L. The bead-like chains of rootlets associated with the endotrophic form described by McDougall (1914) have been found most common in this vicinity when the roots have contact with abundant, moist organic matter. Evidence of surface growth of the fungus or direct connections with the inner hyphae were not found in roots collected during July and August, 1927. Disintegration of bead-like chains of rootlets was observed, but it is not certain that this condition is always associated with drying of leafmold as occurred during two weeks recorded in August. If the beaded rootlets always indicate the fungus development, this form is present wherever the species occurs in this timbered area.

Acer negundo L. An endotrophic form producing beaded rootlets as in *A. rubrum*. Since this condition was found only on trees growing in heavy sod or leafmold it is probable that the same or a closely related fungus produces it.

Quercus palustris L. Two ectotrophic forms have been found in this region. The first has been found only in moist leafmold and is distinguished by the dense masses of coral-like rootlets which appear to be in no way connected with each other by fungous filaments. The surface of these mantles was, however, covered by uniformly distributed, protruding strands. (Fig. 3.) Free-hand and stained sections showed



Fig. 3—Mycorrhizal roots of pin oak. (*Quercus palustris*). Left. Form 1. Group of coral-like roots, showing few strands passing between grayish-brown mantles. Form 2. White mantles, showing rhizomorph-like strands passing between mantles and into a decomposing leaf.

an outer layer of radially elongated cells and a compact mantle. The second form produces white mantles from which groups of strands may pass into the soil, decomposing leaves, or to other mantles. (Fig. 4.) The mantle surface was found smooth and dense. This form was found most abundantly in this vicinity.

Quercus Macrocarpa Mich. White, compact mantles similar to those produced on *Q. alba* were collected and sectioned in July and August,

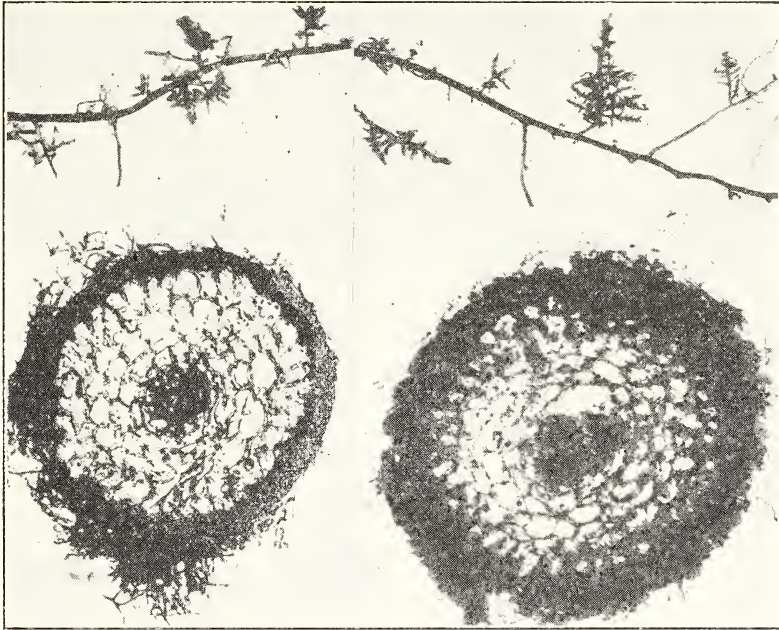


Fig. 4—Left. Mycorrhiza of white oak (*Quercus alba*). Group of white mantle-covered roots, showing development of long mantles. Transverse section of root, showing darkly stained fungous mantle and strands between radially elongated cells. Right. Compound mycorrhiza of swamps white oak (*Quercus bicolor*). Fresh roots, showing brown mantles overlapping the loosely constructed white oncs. Transverse section of compound mycorrhizal root, showing fungus between cells of third cortical layer on side of root having two mantles. Easily separated outer mantle does not send strands through the inner.

1927. Cells of the outer layer were found surrounded by the fungus filaments and the usual growth passed between cells of the first cortical layer. (Fig. 5.) The surrounded cells were apparently not discolored, but distortion, rounding of edges and a reduction in size was observed. While some cells were radially elongated, this did not occur in a regular manner. Found on this plant whenever the roots grow in leafmold, it seems to be widely distributed. An ectotroph in roots of this tree has been described and figured by Lohman (1926).

Quercus bicolor Will. The development of compound or dual-fungus mantles was found frequently in this region. The inner filamentous mantle characterizes the common form on this species. This is filamentous and white or gray in late fall. The secondary brown mantle, which develops outside the first, becomes highly appressed. While the strands of the outside mantle were not found intermingling or passing through the inner, an attraction either to the root or the other fungus is evident. A condition almost identical to this has been described by Masui (1926) on the roots of *Q. paucidentata* Fr. The secondary or outer fungus has not been found existing alone on roots.

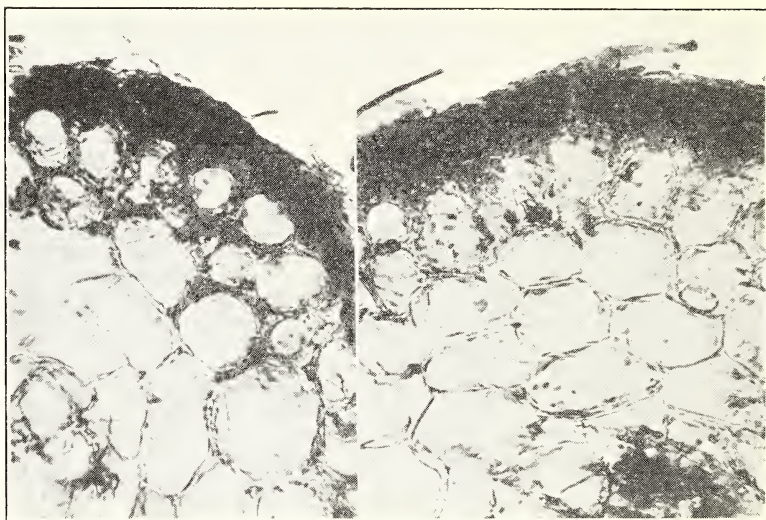


Fig. 5—Left. Transverse section, mycorrhizal root of bur oak (*Quercus macrocarpa*), showing dense, compact mantle and strands between cells of second cortical layer. Right. Transverse section, mycorrhizal root, (form 2) of pin oak (*Quercus pulstris*), showing loose mantle and strands between radially elongated cells.

Quercus alba L. An ectotropic form was found on all roots examined. Groups of white filamentous loose mantles occurred most frequently between the lower layers of moist leafmold. It is apparently the form 4 described by McDougall (1914) on this species.

Fraxinus americana L. An examination of roots in August showed the production of a brown mantle. This seemed to consist of a thin weft of mycelium, which served to prevent further growth of the enclosed roots in the same manner as thicker mantles. Since it has not been found in large groups of shortened roots or on parts of every root system even in a most favorable condition, the association is probably not so important in the life of the tree. An ectotroph and endotroph apparently due to the same fungus has been described by Lohman (1926) in *F. pennsylvanica*, var. *lanceolata*.

Rubus Flagellaris Will. The presence of bead-like structures among roots taken in July and until August 15, 1927, indicated that an endotroph similar to that of *Acer rubrum* might be present. While the roots sectioned later did not demonstrate the presence of a true endotroph, mycelia were found in the outer and dark colored epidermis of young roots. Apparently a parasite, the intracellular growth did not appear unlike that of a true endotrophic form after seasonal development.

Corylus Americana Walt. Two conditions of mycorrhiza development were found. An endotrophic white mantle was found on roots growing in moist locations. It cannot be considered common in this vicinity. The arrangement of young roots into a bead-like structure resembles that described for *Acer rubrum* by McDougall. Since sections

of roots did not reveal the fungus, it was probably a normal habit of root growth.

Summary. The ectotrophic forms of mycorrhiza found most commonly on forest trees are in general favored in development by the presence of leafmold or other surface organic deposits. The fungi producing mycorrhizas on species of *Quercus* are more nearly dependent upon this condition.

While the production of mycorrhizas by several fungi on the same plant has been observed in case of *Fagus* and *Quercus*, there are indications that an even greater number of fungi may be involved.

A compound mycorrhiza of *Quercus bicolor* gives some evidence that the attraction forces of certain fungi toward young growing roots of trees is greater than the inhibiting forces between two fungi.

An incompletely formed mantle found frequently on roots of *Cercis canadensis* indicates that the rate of growth of the fungus may be a determining factor in mantle formation.

The true endotrophic forms here observed have been previously described.

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RECORDS OF BLUEBERRY INSECTS IN INDIANA.¹

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During a survey of the blueberry regions of northern Indiana in 1925, observations were recorded on the insects of the high-bush blueberry (*Vaccinium corymbosum* Linn.) and the low-bush blueberry (*V. pennsylvanicum* Lam.). In a continuation of the records in 1926, insects of the dry land blueberry (*V. vacillans* Kalm.) were included. The following counties were surveyed: Fulton, Allen, Noble, DeKalb, Steuben, Lagrange, Kosciusko, Elkhart, St. Joseph, Marshall, Pulaski, Starke, Jasper, Newton, Lake, Porter, and Laporte. While it is recognized that these notes do not include all local areas in which blueberries are found, it is hoped that, as preliminary records of prevalence and extent of injury, they may serve as a basis for future, more extensive investigation.

In blueberry regions along the Atlantic Coast, Coville² reported the high-bush blueberry (*V. corymbosum*) to be relatively free from insect injury. Records of species occurring on this plant in the field were not given. Woods³ has reported the insects found on the low-bush blueberry (*V. pennsylvanicum*) and the dryland blueberry (*V. vacillans*) in Maine. In accordance with a former record,⁴ extensive injury to the fruit of *V. pennsylvanicum* was attributed to the larva of the apple maggot (*Rhagoletis pomonella* Walsh). While the identity of the insect causing the injury was doubtful, due to variations in the size of larvae, the adult fly was recognized.

The method employed in obtaining records on the three species of blueberries included: field observation of insects present, types of injury and extent, and collections in case a field identification was found impossible. The number of areas surveyed in each county and the number in which the various insects were found is recorded in Table I.

In distribution the high-bush blueberry (*V. corymbosum*) was found only in very moist peat soils, sphagnum, and tamarack bogs in the lake region. The low-bush blueberry (*V. pennsylvanicum*) was found in the edge of swamps along with the high-bush (*V. corymbosum*) and also in moist, sandy oak woods. Apparently adapted to a wide range of soil conditions, this species is, however, restricted to soils covered by an upper layer of leaf mold or other natural means of controlling moisture.

¹ Contribution from the Department of Entomology and Horticulture, Purdue University Agricultural Experiment Station, Lafayette, Indiana.

² Coville, F. V. Experiments in blueberry culture, U. S. D. A. Bur. Plant Indust. Bull. 193. 1910.

³ Woods, W. C. Blueberry insects in Maine. Maine Agr. Exp. Sta. Bul. 244. 1915.

⁴ Woods, W. C. A note on *Rhagoletis pomonella* in blueberries. Jour. Econ. Entom. 7:398-400. 1914.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

The dryland blueberry (*V. vacillans*) was found only in sandy oak woods and open barren sections. While the cultivation of blueberries is not of commercial importance, the three species mentioned are native and generally adapted to the acid peat and sandy soils in the northern one-third of Indiana.

TABLE I. Total number of areas surveyed in each county and the number in which the insects were recorded.

County	Total Areas Surveyed	Leaf Beetle	Fruit Worm	Stem Gall	Leaf Tier
Lake	4	1		3	4
Porter	6	1		6	6
Laporte	4	1		4	4
Newton	2			2	2
Jasper	5			5	1
Starke	2			2	
Pulaski	1			1	
St. Joseph	4		4	4	
Elkhart	2		2	2	
Kosciusko	5			5	
Lagrange	5		5	4	1
Steuben	3			3	
Dekalb	2			2	
Fulton	2			2	
Allen	3			2	
Noble	5			4	
Marshall	1			1	

Leaf Beetle (*Galerucella cavicollis* Lec.). Adult beetles were found on leaves of *V. corymbosum*. Considerable injury to plants isolated near the edge of swamps was found due to eating away of young growing tips of laterals. Near Shelby in Lake County and Valparaiso in Porter County many plants near the edge of swamps were partially defoliated. This species was readily distinguished from *Galerucella decora* Say, which was found in the same swamps on willow, by the much longer thorax and distinct reddish color. Recorded in only one additional location, near Pine Lake in Laporte County, it is apparently more prevalent in the region bordering Lake Michigan.

Fruit worm. A small, uniformly white dipterous larva occurring singly in the berries of *V. vacillans* and *V. pennsylvanicum* in dry locations was found in St. Joseph, Elkhart, and Lagrange counties. The intact berries and stringy contents when infested indicated that it was probably the larva of the apple maggot (*Rhagoletis pomonella* Walsh) described by Woods in fruit of *V. pennsylvanicum* in Maine. Since adults were not reared, the identity of the insect was uncertain.

Dried fruits remaining on the plants of *V. vacillans* after normal ones had ripened and dropped were found to contain larvae of an insect other than the described fruit worm. Small masses of frass were observed in the calyx end, usually underneath the calyx lobes, which were curled inward upon drying. This was the larva of some small lepidopteran, apparently causing slight damage, since it was observed only late in the season.

Stem-gall insect (*Hemadas nubilipennis* Ashm.). Records of the occurrence of this insect on *V. corymbosum* and *V. pennsylvanicum* were obtained in all counties surveyed. The cause of the gall was first ascribed by Ashmead⁵ to a new genus and species of cynipid, *Solenozopheria vaccinii*. The same insect is listed as causing the gall by Stebbins⁶ and Thompson.⁷ Rearing experiments carried out by Driggers⁸ have established the cause of the gall to be a chalcidoid (*Hemadas nubilipennis*), while the previously described *Solenozopheria vaccinii*, along with two other chalcidoids, *Ormyrus vacciniicola* and *Eurytoma solenozopheriae*, and a species of *Decatoma*, was probably a parasite or guest fly.

The reniform, pithy, polythalamus galls occurred on young wood produced during the current season. Injury consisted in a reduction of the fruiting surface for the following season, since fruit was borne only on wood produced during the previous growing season (fig. 1). Terminals were found containing galls more often than the more slowly growing laterals. This habit, together with the widespread occurrence of the insect, makes it a serious pest of both *V. corymbosum* and *V. pennsylvanicum* in Indiana.



Fig. 1—Galls of *Hemadas nubilipennis* on the high-bush blueberry (*Vaccinium corymbosum*). (Left). The reniform, pithy gall. Showing openings through which adult insects have emerged. (Right). Entire branch. Terminal and first lateral branch (A) killed by gall.

⁵ Ashmead, W. H. Gall insects. Trans. Amer. Entom. Soc. 14:149. 1887.

⁶ Stebbins, F. A. Gall insects of Springfield, Mass., and vicinity. Springfield Mus. Nat. Hist. Bul. 2. p. 46. 1909.

⁷ Thompson, M. T. Catalogue of American Gall insects. Publ. R. I. Hospital Trust Co. p. 25. 1915.

⁸ Driggers, B. F. Galls on the stems of cultivated blueberry (*Vaccinium corymbosum*) caused by a chalcidoid, *Hemadas nubilipennis* Ashm. Jour. New York Ento. Soc. 35:253-259. 1927.

Leaf tier (*Telphusa latifasciella* Cham.). Larvae from young leaf tips webbed together in May were collected in 1926. From two collections in Lake County on May 1 and one sent from Lagrange County on May 8, adult insects were obtained. Pupation had occurred before May 30 and first adult moths emerged before June 14, when rearing boxes were first opened.

This insect has been reported by Morse⁹ on the "huckleberry" in New Jersey. It is not known, however, whether the true black huckleberry (*Gaylussacia baccata*) or one of the blueberry species was here referred to.

The larva of this gelechiid has been found only during May. Tying entire groups of very young leaves, which seldom make further growth, an appreciable amount of injury may result. Its distribution throughout the area is known to include Lake, Porter, Lagrange, Laporte, Newton, and Jasper counties.

⁹ Morse, S. R. Insects of New Jersey. Ann. Rept. N. J. State Museum, p. 555, 1909.

INSECTS OF INDIANA FOR 1927.

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The following account is a summary of the more important insect problems of the year, intended as a seasonal record and a basis for future work in predicting insect problems.

Weather Conditions. In general the month of January was normal, taking the state averages as a whole. However, in February the mean temperature was over nine degrees above normal with a normal rainfall. In March the rather high temperatures about the middle of the month brought the average temperature somewhat above normal and the month was in general rather mild with approximately normal precipitation. The temperature was about normal in April but there was an appreciable excess of rainfall. May was slightly below normal in temperature but noticeably above normal as regards precipitation. The excessive rainfall of April and May greatly interfered with farm

TABLE I. Comparative Monthly Weather Data for Indiana, 1927

MONTH	Temperature		Precipitation		Number of Days		
	State Mean	Departure From Normal	State Average	Departure From Normal	Clear	Partly Cloudy	Cloudy
	°F.	°F.	Ins.	Ins.			
January, 1927.....	28.6 27.9	4.6 -0.7	3.05 3.38	1.21 +0.33	10 9	7 8	14 14
February, 1927.....	29.6 38.8	4.1 +9.2	2.54 1.64	1.19 -0.90	9 9	7 8	12 11
March, 1927.....	40.7 44.0	3.9 +3.3	3.86 4.69	1.54 +0.83	10 10	8 8	13 13
April, 1927.....	52.0 52.5	2.1 +0.5	3.49 5.91	1.23 +2.42	11 8	9 9	10 13
May, 1927.....	62.2 61.1	2.6 -1.1	4.01 7.09	1.07 +3.08	12 8	10 11	9 12
June, 1927.....	71.6 66.9	2.2 -1.7	3.83 3.30	0.96 -0.53	13 15	10 8	7 7
July, 1927.....	75.3 74.0	1.7 -1.3	3.40 3.41	1.05 +0.01	15 16	11 11	5 4
August, 1927.....	73.3 67.4	1.7 -5.9	3.31 3.12	1.07 -0.19	15 16	10 8	6 7
September, 1927.....	67.0 70.6	2.6 +3.6	3.12 4.71	1.02 +1.59	15 16	8 8	7 6
October, 1927.....							

¹ The writer is indebted to H. F. Dietz, B. A. Porter, R. F. Sazama, C. M. Packard, H. K. Riley, L. F. Steiner, and M. M. Justin for records.

operations, especially corn planting. The month of June was colder than normal and precipitation about normal, the cold weather interfering with the growth of corn. During July the temperature more nearly approached normal although still a little below and the rainfall was normal. August was much below normal for temperature, being cool almost the entire month. Precipitation in August was normal. The excessive temperature of September aided corn and permitted development which partly compensated for the cold summer. The late spring and cool season was reflected not only in plant growth but also in the development of insects. (See Table I and figures 1 and 2.)

Incorrect Insect Reports. Every year one or more insect pests, notorious for their damage elsewhere but not in Indiana, have received conspicuous mention in newspapers. Such reports are unfortunate. Insects suspected should always be submitted to an authority before newspaper publicity is given.

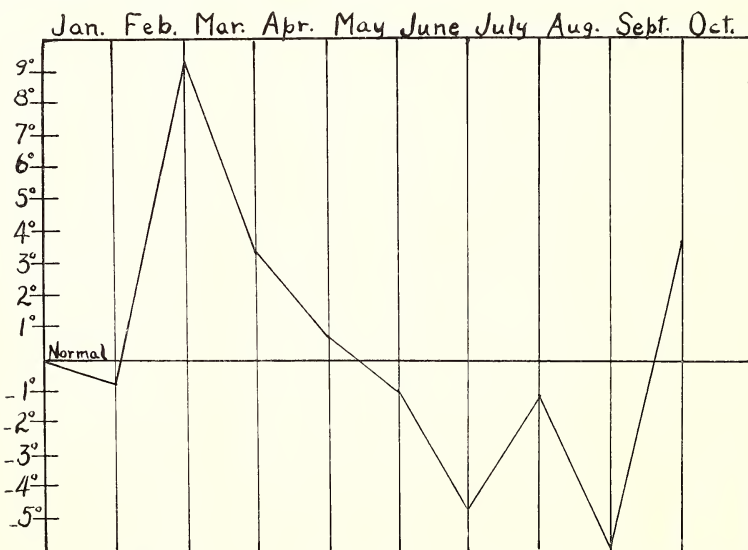


Fig. 1—Departures from normal temperatures in Indiana for the year 1927, based on data in Climatological Data, issued monthly by the U. S. Weather Bureau.

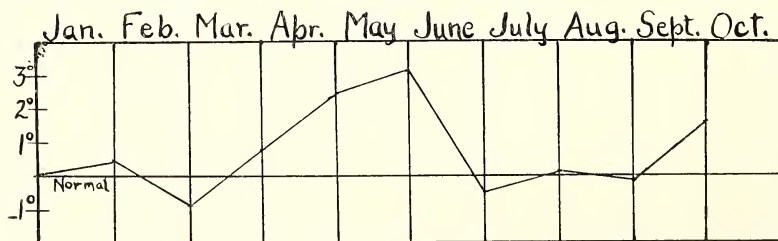


Fig. 2—Departures from normal precipitation in Indiana for the year 1927, based on data in Climatological Data, issued monthly by the U. S. Weather Bureau.

During the last season mistaken identification of insects has been more noticeable than usual, no doubt due to the publicity that has been given the European corn borer. Many insects were mistaken for the corn borer, the most conspicuous ones being the corn ear worm (*Heliothis obsoleta* Fab.), smartweed borer (*Pyrausta ninslei* Heim.), common stalk borer (*Papaipema nitela* Guen.), and parsnip webworm (*Depressaria heracliana* De G.) on wild parsnip. Ladybird beetles (Coccinellidae) were frequently suspected of doing damage which should have been attributed to aphids. In one case a widespread report of the occurrence of the brown-tail moth was circulated, and in this case the insect was none other than our common tussock moth caterpillar.

CEREAL AND FORAGE INSECTS.

Grasshoppers (*Melanoplus femur-rubrum* De G. and *M. differentialis* Thos.) which have been abundant and destructive the past few years reached their peak of abundance last year. In 1927 not a single report of damage was reported. This may have been due to the prevalence of its natural enemies (blister beetle larvae) and to the wet fall of 1926.

White grubs (*Lachnosterna* spp.) were the most destructive in Indiana for many years and increasing trouble may be anticipated three years hence. The outbreak was anticipated following an abundance of beetles in 1926. The grubs were more or less destructive throughout the northwestern quarter of the state and severe damage was reported from the following counties: Benton, Carroll, Dubois, Lake, Laporte, Marion, Marshall, Monroe, Putnam, Rush, St. Joseph and Warren. The principal damage occurred to corn and grass areas, especially golf greens. Potatoes and strawberries were also severely attacked in some cases. The State Statistician received reports of severe losses, amounting to one-half or three-fourths of the corn crop in some areas.

Wireworms (Elateridae) were less destructive than in 1926 according to reports. During January and February reports were received of damage the previous year to onions, potatoes and other crops. During the season only two authentic reports of injury were received—Columbus where wireworms damaged wheat early in the spring and to corn at Marion early in July.

Hessian fly (*Phytophaga destructor* Say) was not important the past year. C. M. Packard, in charge of Hessian fly investigations for the U. S. Department of Agriculture, has studied the situation throughout the state and reports as follows: The anticipated fly outbreak due to heavy volunteer wheat growth in the fall of 1926, did not materialize this spring, due to the prolonged cold, wet weather the past spring which hampered fly activity. Examinations in 42 representative fields throughout the state showed an average of 17 per cent infestation of culms, with a range of 0 per cent to 44 per cent. No serious damage resulted last spring.

Sufficient numbers developed last spring to menace the fall sowing but weather conditions again intervened and prevented any appreciable increase in fly abundance. The weather conditions responsible were

first, drouth which delayed emergence and later low temperature which also delayed emergence and as a result some of the spring puparia are passing the winter as such. Those which did emerge the past fall came out gradually and in comparatively small numbers. Light emergence and oviposition occurred at Lafayette early in September and during the period for Sept. 17 to 28. After a period of practical inactivity, another scattering issuance occurred between Oct. 3 and 20.

The great majority of "fly" in young wheat were still in the larval stage in late November. Although there was much early planting of wheat this fall, fly infestation on the whole has been very light, although occasional fields may be found in which upwards of 40 per cent of the plants are infested.

Chinch bug (*Blissus leucopterus* Say) was nowhere destructive in the state. The spring weather conditions were very unfavorable for the few bugs that passed the winter.

Army worm (*Cirphis unipuncta* Harv.) was unusually scarce in contrast to an abundance the year before. Only one authentic report was received and that from Crown Point, July 19, where they were attacking corn.

Fall army worm (*Laphygma frugiperda* S. & A.) was reported damaging corn at Aurora Sept. 16, this being the only report received.

European corn borer (*Pyrausta nubilalis* Hbn.) was first discovered in Indiana in 1926 and as reported in last year's records, six counties (39 townships) in the northeastern corner of the state being infested. The scouting work in 1927 revealed ten additional counties (90 townships) to be infested. Inasmuch as facilities did not permit scouting thoroughly to the limits of possible infestation in 1926, many of these supposed new infestations may have been 1926 infestations not discovered until 1927.

Intensive investigations are being made by state and federal agencies in an effort to secure effective and practical controls and to establish the parasites. To retard the rate of increase in the infested area and check the spread into the corn belt regions, an intensive campaign was made last spring to clean up the crop residues in which the borer passes the winter. This resulted in checking the rate of increase and demonstrated the value of cleaning up these residues. No other controls are as yet available. Aside from the extensive entomological research, which includes parasite introduction, the corn borer problem is being studied from the standpoint of agronomic practices.

The common stalk borer (*Papaipema nitela* Gn.) was noticeably more abundant and widespread than for many years, more than 150 inquiries with specimens for identification being received. The first few reports were received June 6 to 18 from the southern half of the state, injury being observed on potatoes, tomatoes and corn. Beginning with June 20, reports became numerous and from all parts of the state, corn being the chief host. Tomatoes were frequently attacked and occasionally reports were received of injury to potatoes, wheat, oats, popcorn, mint, dahlia, zinnia, aster, cosmos, hollyhock, and rhubarb. The reports continued to come in until after the middle of August although the majority were received between June 20 and July 31. The

corn borer situation was doubtless responsible for many of the reports received, but the accompanying map, (fig. 3) showing the range of injury distribution for 1926 and 1927 based on authentic reports received, indicates the greater abundance and distribution in 1927.

Corn flea beetle (*Chaetocnema pulicaria* Melsh.) destroyed 10 acres of corn at Brownstown in late June.

Corn webworm (*Crambus caliginosellus* Clem.), which was so abundant in 1926, was practically absent in 1927 and no reports of injury were received.

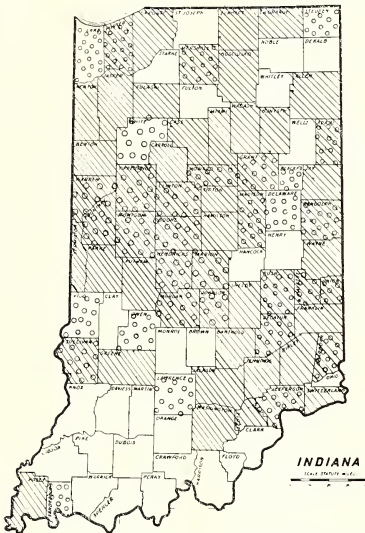


Fig. 3—Distribution of the common stalk borer in 1926 (circles) and in 1927 (diagonal lines) according to reports and observations.



Fig. 4—Distribution of southern corn root worm injuries during 1927.

Corn ear worm (*Heliothis obsoleta* Fab.) was reported on field corn, sweet and popcorn during the season June 25 to Sept. 17 from Aurora, Campbellsburg, Cicero, Evansville, Warsaw, Huntington, Indianapolis, Portland, Remington and Rushville. Damage to garden beans was reported from Indianapolis. In general was more widespread and destructive than any year since 1921.

Corn seed maggot (*Hylemyia cilicrura* Rond.) damaged planted cucumber seed at Plymouth, June 21.

Southern corn root worm (*Diabrotica 12-punctata* Fab.) was one of the most destructive corn insects in the state and more so than ever before so far as our own observations of the past 15 years record. First reports were received July 2 and continued throughout the month and they were especially numerous during the middle third of July. Reports read "20 acres practically ruined," "one-third to one-half of corn destroyed," "abundant and destructive throughout country," etc., indicating the seriousness of the outbreak which was no doubt largely the result

of the wet spring which was responsible for much weediness and the production of conditions ideal for the beetles to lay eggs. The accompanying map, (fig. 4) gives the distribution according to inquiries received. All records based on specimens excepting the Marshall County record.

The adult beetles were reported damaging young corn plants at Kitchel, June 18. The beetles were abundant and destructive at Shelbyville, July 30, by eating into the green pods of garden beans.

Cutworms (*Noctuidae*) were at least normally abundant. Reports of serious damage were received from 18 counties as indicated in figure 5. The records for Pulaski, Miami, Clinton, Delaware, Vigo, Morgan,



Fig. 5—Distribution of conspicuous cutworm outbreaks in 1927. Cross-hatched refer to *Agrotis ypsilon*. Other counties species unknown.



Fig. 6—Distribution of the Mexican bean beetle in 1927.

Gibson, Howard, Vanderburgh, and Warrick counties were accompanied by specimens, all proving to be the common greasy cutworm or overflow worm (*Agrotis ypsilon* Rott.). The first of these late season cutworm reports, all of which were apparently *A. ypsilon*, came from Kokomo, June 27, where 20 acres of corn were reported destroyed. The reports all came in the last of June and the first half of July and the outbreaks were doubtless the result of the excessive precipitation in April and May. For a number of years, this species has been a serious pest in the overflow land of Gibson, Posey, and Vanderburgh counties following late overflows of the Wabash and White rivers. Corn was the principal crop damaged although some reports referred to truck crops.

Leather jacket larvae (*Tipulidae*) damaged alfalfa near Goshen May 9. According to the county agricultural agent, a number of fields were seriously damaged. The field in which the greatest damage

occurred had been in alfalfa continuously for six years. There was also considerable blue grass scattered in the field. In this 12-acre field two to three acres were completely destroyed and the remainder more or less damaged. Last year, the same farmer experienced similar injury and plowed up two acres where damage was most severe. Larvae were found in large numbers about the crown of the plant and the roots, both being oftentimes girdled. The plants that had been dead for some time easily lifted from the soil.

Clover leaf weevil (*Hypera punctata* Fab.) reported damaging sweet clover at Saratoga and Portland May 19 and 20, respectively.

Green stink bug (*Acrosternum hilaris* Say) was abundant in some localities in Southern Indiana. In Bartholemew County there was good evidence that they were responsible for shriveling of soybean seeds in the pod.

Bean maggot (*Hylemyia cilicrura* Rond.) was apparently responsible for destruction of nine acres of soybeans at Portland late in June. Larvae supposed to be this species damaged cucumber plants at Plymouth, June 18.

Termites (*Reticulitermes flavipes* Kell.) were conspicuously abundant in field corn stalks at Richmond early in October. They were also found common in sweet corn stalks at Lafayette.

VEGETABLE INSECTS.

Mexican bean beetle (*Epilachna corrupta* Muls.) was very abundant and destructive in the southeastern quarter of the state. The accompanying map (fig. 6) gives the present known distribution in the state. No reports of injury have been received north of southern Hamilton County. Dietz reports the farthest north record at Ashley, Dekalb County.

Cabbage maggot (*Hylemyia brassicae* Bouche) damaged radishes at Sheridan early in June.

Cabbage worm (*Pontia rapae* L.) was normally abundant throughout the state.

Cabbage aphid (*Brevicoryne brassicae* L.) caused little trouble judging from general observations and reports received. The report of abundance and damage came from Terre Haute June 8.

Onion maggot (*Hylemyia antiqua* Meig.) damaged onions at Elkhart, Ashley, Hobart, Hamilton, Hammond and Warsaw, all in the north end of the state. Reports were received in June and early July.

Woolly bear caterpillar (*Diacrisia virginica* Fab.) damaged onions at Pleasant Lake July 13.

Blister beetles (*Epicauta* spp.) were about equally abundant as in 1926 and reports came in between June 20 to Sept. 1 from Anderson, Bridgeport, Cannelton, Columbus, Fort Branch, Goodland, Kempton, Lafayette and North Vernon. Dahlias and asters were the principal flower garden plants attacked. Many vegetable crops were infested, especially potato, egg plant, and swiss chard. We continue to get excellent control with sodium fluosilicate dust.

The variegated cutworm (*Peridroma magaritoza* Haw.) was common in many greenhouses. Especially noticeable was injury in late April and early May in a greenhouse at Indianapolis where they defoliated tomato plants and caused heavy loss by eating in heads of greenhouse cauliflower. Cutworms (probably *Euxoa* spp.) were generally troublesome in Northern Indiana in gardens during May and early June.

The potato flea beetle (*Epitrix cucumeris* Harr.) was abundant on potato at Nappanee June 22 and Dietz reports injury to potato at Paoli and to tomatoes throughout Marion County.

Potato leafhopper (*Empoasca mali* LeB.) was damaging potatoes at Berne during June.

Striped cucumber beetle (*Diabrotica vittata* Fab.) was destructive to cantaloupe, cucumbers, watermelons and squash in the following localities according to reports received: Terre Haute, Spencer, New-castle, Valparaiso, Goshen, Rockville, South Bend, Manchester, Roanoke, Franklin, and Rensselaer.

Melon aphid (*Aphis gossypii* Glov.) was apparently not as common as usual for only one report was received, this coming from Silver Lake June 26.

Rhubarb curculio (*Lixus concavus* Say) injured rhubarb at Rochester and Spencerville during May.

Pickle worm (*Diaphania nitidalis* Stoll) was destructive to cucumbers at Logansport, Madison and Princeton the last of August and early September.

Squash vine borer (*Melittia satyriniformis* Hon.) was destructive to squash at South Bend, Peru, Fort Wayne, and Manchester and to pumpkin at Muncie. All reports were received the last of July and early August.

Mole cricket (*Gryllotalpa borealis* Burm.) damaged potatoes early in September at Vincennes. This insect was also received from Francesville and Warsaw during September but not reported doing injury.

Tomato worms (*Phlegethontius quinquemaculata* Haw.) was destructive to tomato at Campbellsburg and Kingsburg the first half of August.

The potato flea beetle (*Epitrix cucumeris* Harr.) damaged tomato at Economy, June 7 and corn at Brownstown, July 5.

The striped flea beetle (*Phyllotreta sinuata* Steph.) reported damaging strawberry at Marion, June 22.

Blister beetles were common in many sections of the state, but not as abundant as in 1926 according to observations by both Dietz and the writer. The black blister beetle (*Epicauta pennsylvanica* DeG.) was most often reported. This species was injuring potatoes, tomatoes, dahlia and asters from July 29 to Sept. 1, at Columbus, North Vernon, Fort Branch, Goodland, Lafayette, Indianapolis, and Zionsville. The striped blister beetle (*E. vittata* Fab.) attacked eggplant at Anderson, June 20 and Dietz reports injury to tomatoes July 21 at Franklin. The margined blister beetle (*E. marginata* Fab.) damaged dahlia at Cannelton and Tell City, July 15, to flower garden plants at Lafayette the last of July and Dietz records injury to potato by this species at Kempton. Reports of injury to asters at Bridgeport, July 22, and to potatoes at

Kempton, July 27, but unaccompanied by specimens or descriptions to enable identification of species.

The greenhouse centipede (*Scutigerella immaculata* Newp.) continues as a pest especially of greenhouse radish and lettuce, in many sections of the state. Each year the extent and range of infestation increases.

FRUIT INSECTS.

Codling moth (*Carpocapsa pomonella* L.) was serious as usual. Winter mortality was negligible. The first moths were observed at Bedford in May and L. F. Steiner observed the first eggs in that locality May 9, although none hatched until May 21 owing to cool, rainy weather. Porter observed the first larvae at Vincennes May 20. The cool weather caused the moths to issue over a longer period than usual and as a result there was no distinct period between hatching of the last first brood worms and the early second brood worms. While heavy losses occurred in some orchards, especially where the full quota of sprays was not applied, the season was unfavorable for the insect. During the emergence of the moths the cool evenings were not favorable for egg laying and the destruction of a large share of the crop by spring frosts was a factor which was unfavorable for optimum increase of the codling moth. Also, during the cool weather of August most of the worms went into hibernation, few of them pupating. As a result there were few pupae from which moths could emerge during late August and the first half of September, when conditions were favorable to the insect, and consequently the number of late worms was reduced to a minimum.

The apple maggot (*Rhagoletis pomonella* Walsh) was very destructive to apple at Bristol and other points in Elkhart County.

Plum curculio (*Conotrachelus nenuphar* Host.) was unusually severe according to Dietz who reports four to eight stings per apple near Indianapolis and 80 per cent of the cherries infested in Lawrence and Orange counties. Dietz says that from reports received, this insect is more abundant on cherries than it has been for several years. Our observations indicate normal abundance excepting where spray operations were incomplete or disregarded, in which cases heavy infestations occurred.

Peach tree borer (*Aegeria exitiosa* Say) was very abundant, largely due no doubt to the fact that some orchards received no treatment in the fall of 1926 because of unfavorable weather conditions. Such orchards were heavily infested.

San Jose Scale (*Aspidiotus perniciosus* Comst.) was somewhat more abundant than in 1926. Winter mortality, according to B. A. Porter, was 69 per cent on old neglected peach trees. It is thought the mortality would be lower in younger orchards. The first brood crawlers appeared at Vincennes about June 1. During the warm, dry weather of October in Southern Indiana the scale multiplied extremely rapidly.

The peach lecanium (*Eulecanium nigrofasciatum* Perg.) was reported abundant on peach at Mitchell during September.

Tarnished plant bug (*Lygus pratensis* L.) was very abundant in

Knox County and vicinity, according to B. A. Porter, and caused considerable damage by "cat-facing" peaches. Porter and Sazama found that certain other species of plant bugs also cause "cat-facing." H. F. Dietz reported tip injury to peach nursery stock at Burns City, Terre Haute, Vincennes and Washington, to flowering spikes of gladioli, causing malformed flowers, at Spencer and to dahlia flowers at Indianapolis and Zionsville. There was probably more damage to gladioli than recorded because most growers credited damage to dry or hot weather which likely was the plant bug injury. Other reports of injury to gladioli and dahlias came from Spencer, Goshen, Liberty, and Plymouth.

Green soldier bug (*Acrosternum hilaris* Say) was reported by Doctor Porter as injuring peach fruit at Vincennes during August. The nymphs were observed feeding on the fruit.

Apple aphids (*Aphis avenae*, *Aphis pomi* DeG., and *Anuraphis roseus* Baker) were comparatively scarce early in the season. At Bedford, April 10, stem mothers and a few young of *A. avenae* and an occasional stem mother of *A. roseus* were present on almost every apple cluster and likewise with every aphid colony was an egg or larva of the common syrphid, *Syrphus americana*. When the same orchard was visited May 2 and 20, respectively, scarcely an aphid remained. On the latter date an occasional cluster of *A. roseus* was observed and apparently the first winged individuals appeared that day. Beginning about June 1 the aphids began to reappear slowly and by June 24 aphids were abundant everywhere. *A. roseus* was spotted but *A. pomi* occurred in large numbers. They were especially destructive to young trees and small trees which had been top-worked following the severe blight damage of 1926. Apple nursery stock was also heavily infested by *A. pomi*.

Black cherry aphid (*Myzus cerasi* Fab.) reported abundant at Clermont, Danville, Greenwood, Indianapolis, Parker, and Pleasant Lake, all localities in center of state excepting the last, which is in the north-eastern corner. They were especially noticeable in June.

Rusty brown plum aphid (*Hysteroneura setariae* Thos.) was abundant on plum at Clermont, Fishers, Greenwood, Indianapolis and Marion.

Grape aphid (*Macrosiphum illinoisensis* Shimer) was reported conspicuously abundant from Terre Haute, June 24, our only report.

Currant aphid (*Myzus ribis* L.) was reported only twice during the season and from Greentown and Clermont. Dietz reports a scarcity of this aphid.

Woolly apple aphid (*Eriosoma lanigerum* Haus.) was unusually abundant on apple throughout the state, reports being received from the last of June to early in August. They were specially noticeable in orchards at breaks and cuts on the branches of small trees where injured earlier in the season by hail. According to Dietz the aerial form was found on apple nursery stock in every nursery in which apple stock was grown.

Apple leafhopper (*Empoasca mali* LeB. *fabae* Harv.) was very abundant and especially serious in southern Indiana to young trees and those top-worked because of blight damage in 1926. The injury was

most noticeable in June when aphids were abundant and in some cases were more responsible for injury than aphids.

Cherry slug (*Caliroa cerasi* L.) was reported only from Lincoln early in July. The last two years have been years of comparative freedom from this insect. Early defoliation by cherry leaf spot probably starved out any slugs which were present.

Rose chafer (*Macrodactylus subspinosus* Fab.) reported damaging rose and apple at Crown Point, June 18, and to grape at LaGrange, June 20. Not nearly as abundant as past few years.

Cotton caterpillar moth (*Alabama argillacea* Hbn.), which was so abundant in 1925 and 1926, was not once observed damaging fruit this year. One unverified report from Vincennes was received.

Yellow-necked apple caterpillar (*Datana ministra* Drury) was reported common on apple at Bargersville and Williamsport in July.

Cecropia moth caterpillar (*Samia cecropia* L.) stripped apple trees at Sheridan early in August.

Bagworms (*Thyridopteryx ephemeraeformis* Haw.) was common in the southern half of Indiana, defoliating or seriously attacking cedar, arborvitae, soft maple, white pine, juniper, willow, boxelder, spirea, tamarisk, dogwood, rose, and apple, especially young, unsprayed apple. The first report was received July 6 and the last August 13. Dietz reports it more abundant in nurseries than usual.

Lesser peach tree borer (*Synanthedon pictipes* G. & R.) was about normal as in 1925 and 1926.

Shot hole borer (*Eccoptogaster rugulosus* Ratz.) was not conspicuous. Some injury was noticeable to winter injured trees. Reports came to us from Indianapolis, Anderson, Columbus, Elwood and Goshen, most of them reporting damage to peach and cherry.

European red mite (*Paratetranychus pilosus* C. & F.) was recorded by Dietz from Indianapolis on apple, cherry, plum and peach.

Wavy-striped flea beetle (*Phyllotreta sinuata* Steph.) damaged strawberry at Marion, according to a report received June 20.

Thousand-legged worms (*Myriopoda*) were reported eating into the fruits of strawberry and causing appreciable loss at Princeton, May 18. Also similar reports from Monticello, June 28.

Strawberry leafroller (*Ancylis comptana* Frohl.) is common throughout the state. Dietz reported it as destructive at Bristol, Goshen, Logansport and Peru.

Strawberry crown borer (*Tygloderma fragariae* Riley) was very common and destructive in the Borden area in Clark County, according to Dietz. The wild host in this region was sterile strawberry or cinquefoil (*Potentilla* spp.). Isolated infestations were reported by inspectors from Bristol, Logansport and Peru, either in low-lying or creek bottom strawberry patches. Attacks by the borer in these localities were all followed by an invasion of the fungus, *Schlerotium* sp.

Strawberry slug (*Harpiphorus maculatus* Nort.) was reported early in June damaging strawberries at Albion and Shelby.

SHADE TREE AND SHRUB INSECTS.

Cottony maple scale (*Pulvinaria vitis* L.) was apparently about as abundant and destructive as in 1926 according to reports and observations. The following counties reported abundance of the insect: Adams, Blackford, Boone, Cass, Decatur, Delaware, Fayette, Grant, Hamilton, Hendricks, Henry, Howard, Huntington, Jasper, Jay, Madison, Marion, Miami, Morgan, Randolph, Rush, Shelby, Tippecanoe, Tipton, Union, Wayne, and Wells.

Scurfy elm scale (*Chionaspis americana* Johns.) continues common on American elm throughout the state and is undoubtedly harmful to young trees.

Oyster shell scale (*Lepidosaphes ulmi* L.) was normally abundant, correspondence and observations the past season recording it from all sections of the northern half of Indiana as destructive to peony, poplar, lilac, quaking aspen, soft maple and apple. The two-brooded light brown form began to hatch May 15 at Indianapolis according to Dietz. At Lafayette the first larvae of the one-brooded form were observed May 31 although the first ones probably hatched a day or two before. This species was hatching June 1-5 at Pennville according to Dietz, where the species was infesting bladdernut (*Staphylea trifolia*) and wafer ash (*Ptelia trifoliata*). Dietz also records this species on prickly ash (*Xanthoxylum americanum*). In a real estate addition near Indianapolis Dietz found 50 per cent of young soft maples infested, at least five per cent dead or dying because of this pest.

The Norway maple leafhopper (species unidentified) was reported by Dietz as causing decided dwarfing of very small (6 to 18 inch) Norway maples in nurseries at Indianapolis, Terre Haute and Evansville. Same species found on terminal growth of 6 to 8 foot trees in same nursery. It is these leafhoppers that make the growing of Norway maple from seed an impossibility in Indiana.

An unusual outbreak of the Norway maple aphid (*Periphyllus lyropicta* Kessler) occurred throughout the state. The honeydew was conspicuous and the premature drying and dropping of foliage was quite noticeable. The first report was received June 3 and scattering reports until about June 20 after which many inquiries were recorded up until after July 9. The following counties were represented in the authentic reports: Bartholomew, Cass, Dearborn, Decatur, Delaware, Elkhart, Fountain, Fulton, Grant, Hamilton, Howard, Johnson, Kosciusko, LaGrange, Madison, Marion, Randolph, Ripley, Rush, St. Joseph, Tippecanoe, Tipton, Wabash, Wayne, and Whitley. The writer drove from Lafayette, Indiana, to Monroe, Michigan, the last of June and in every town the presence of these aphids on hard and Norway maples was evident by the honey dew. In some places almost as conspicuous infestations of other species occurred. These included *Drepanosiphum acerifoliae* Thos. on soft maple, *Chaitophorus negundinis* Thos. on boxelder, *Callipterus ulmifoliae* Monl. on elm, and *Callipterus tiliae* on linden.

Spiraea aphid (*Aphis spiraeicola* Patch) was abundant during June on the young shoots of *Spiraea van Houttei* but not more than normally

abundant. The black sooty mold fungus growing on the honeydew dropped on the leaves was very conspicuous.

Snowball aphid (*Anuraphis viburnicola* Gill.) caused serious malformation of the terminal leaves of common snowball at many places in the state.

Woolly beech aphid (*Prociphilus imbricator* Fitch) was common at Noblesville and Carmel early in August.

The tussock moth caterpillar (*Hemerocampa leucostigma* S. and A.) began hatching at Lafayette, June 3, and caused partial or complete defoliation of soft maple and occasionally boxelder, elm, sycamore and wisteria from the following cities: Anderson, Decatur, Franklin, Greensburg, Indianapolis, Lafayette, Logansport, Milroy, Muncie, Plainfield, Shelbyville, Terre Haute, Washington, and Winchester. During March egg masses were reported abundant from Greenfield, Greentown, New Albany and Spencer, in addition to some of the localities where injury was later reported. The outbreak was not as great as anticipated based on abundance of egg masses last winter.

Poplar tent maker (*Melalopha inclusa* Hbn.) was very abundant on Carolina, Lombardy and Volga poplars at Terre Haute during July.

Catalpa caterpillar (*Ceratomia catalpae* Boisd.) scarce, being slightly more common than in 1926. Only two reports were received, namely Rockville and Springport.

Walnut caterpillar (*Datana integerrima* G. & R.) was very abundant and defoliated walnut and pecan trees at Vincennes according to Porter. It was also abundant the last of July at Bedford. Normally abundant over the state as a whole.

Poplar curculio (*Cryptorhynchus lapathi* L.) was reported very destructive to poplar at Williamsport in June and to willow at Marion, June 27. Dietz reported it as bad in the vicinity of Indianapolis on Lombardy poplar and pussy and weeping willow.

Flat-headed apple tree borer (*Chrysobothris femorata* Oliv.) was a serious pest of young hard maple trees at Lebanon, Newburgh, Huron, Huntington, and Indianapolis, the reports coming in during June, and early July.

Common twig girdler (*Oncideres cingulata* Say) was abundant at Waldron in late September and early October, cutting off branches of persimmon.

Ash tree borer (*Podosesia fraxini* Lug.) was destructive to ash trees at Greensburg, July 15 and at Arcadia, Aug. 31.

Common red spider (*Tetranychus telarius* L.) was reported unusually abundant on evergreens throughout the state according to Dietz. We received reports of injury to Norway spruce, red cedar, elm, and phlox from Goshen, Indianapolis, Lafayette, Marion, Pendleton and Richmond, most of the reports coming in during July.

Bladder maple gall mite (*Phyllocoptes quadripes* Shim.) was reported common on maple at Portland during the first half of June.

Imperial moth caterpillar (*Basilona imperialis* Drury) partially defoliated Norway maples at Princeton early in September.

Bagworms (*Thyridopteryx ephemeraeformis* Haw.) were common

on deciduous and coniferous trees in southern Indiana as reported on page 455.

Hickory horned devil (*Citheronia regalis* Fab.) was common on maple at Decatur in late September. Many specimens were sent in but as unrecognized possible pests rather than as known pests.

FLOWER GARDEN AND ORNAMENTAL GREENHOUSE INSECTS.

Iris borer (*Macronoctua onusta* Grt.) was reported from Bluffton, Greenwood, Goshen, Indianapolis, Lafayette and South Bend and was most destructive in city gardens, no serious trouble having been observed in open field plantings. According to Dietz the eggs began hatching April 15 at Indianapolis and because of cool weather continued through May. He observed the adult emergence in cages from Sept. 28 to Oct. 15, many being crippled because of dry conditions. Dietz observed the following hosts in 1927: *Pongoniris* spp. et var., *Iris pseudacorus*, *I. (Evansia) tectorum*, *I. versicolor*, *I. sibirica*, and *I. spuria*. *Iris graminia* not infested.

Chrysanthemum midge (*Diarthronomyia hypogaea* Coq.) was destructive in a Fort Wayne greenhouse in February and Dietz reports an outbreak at Washington and in northwestern Indiana.

Chrysanthemum leaf miner (*Phytomyza chrysanthemi* Kowarz) was damaging chrysanthemum at Rushville during September.

Bristly rose slug (*Cladius isomerus* Nort.) was common and destructive to garden roses in the vicinity of Indianapolis during June according to Dietz. Other rose slugs occurred commonly in all sections of the state.

Rose beetle (*Macrodactylus subspinosus* Fab.) damaged roses at Crown Point, June 18.

Rose leaf hopper (*Empoasa rosae* L.) was generally common.

Rose scale (*Aulacaspis rosae* Bouche) was reported on rose at Indianapolis.

Cyclamen mite (*Tarsonemus pallidus* Banks) was observed by Dietz in greenhouses at Columbus, Hartford City, Indianapolis, Kokomo, Richmond and Washington on the following hosts, listed in order of importance: Chrysanthemum, Chatelaine begonias, cyclamen, snapdragon, stevia, geranium, and annual larkspur. He found them for the first time out-of-doors this year, at Indianapolis, Richmond and Washington, on hardy larkspur. The light blue *Delphinium belladonna* was very susceptible and in hybrid strains the dark blues seem most susceptible.

The common bulb mite (*Rhizoglyphus hyacinthi* Boisd.) were observed injuring gladiolus bulbs at Mathews, Newcastle and Indianapolis by H. F. Dietz. He observes that the trouble at Mathews was due to storing bulbs in crates previously used for tulips and at the other two places it was due to planting gladioli following Dutch bulbs. Injury to Madonna lily was observed at Columbus, Indianapolis, and Spencer. This mite (Ewing det.) was abundant on bulbs of spider lily (*Ismene calathina*) received March 26 from Greenfield.

Aster woolly root aphid (*Prociphilus erigeronensis* Thos.) continues as a common pest of aster and other flower garden plants throughout

the state. Dietz found it common in a garden at Indianapolis. We have had inquiries from Attica, Coalmont, Lafayette, Leesburg, Madison and Montgomery. Most of the reports were received in July.

Nasturtium aphid (*Aphis rumicis* L.) was common at Universal the first of July. No other reports received in correspondence.

A wasp (*Chorion ichneumoneum* L.) was reported as annoying digging burrows in flower gardens and lawns at Peru and Ft. Wayne early in August. At the latter place hydrangea plants were being killed.

Tarnished plant bug (*Lygus pratensis* L.) caused considerable loss to a dahlia grower at Spencer the middle of July. The grower reported that these bugs "sap the life from gladioli spikes just as the spikes appear above foliage. They work on spikes from then on to the blooming stage if the spike can hold out that long, which is impossible in most cases. Have seen 100 or more bugs on a single spike."

Common red spider (*Tetranychus telarius* L.) was frequently reported damaging phlox and other garden flowers in central Indiana during July.

Mealy bugs (*Pseudococcus* spp.) were common throughout the state on lemon trees, coleus, and fuschia.

PESTS OF STORED PRODUCTS.

Bean weevils (*Mylabris obtectus*. Say et ? spp.) were repeatedly reported as attacking stored garden beans, cowpeas and soybeans.

Angoumois grain moth (*Sitotroga cerealella* Oliv.) was damaging to stored sweet corn at Thorntown in May.

One of the flour mites (*Tyroglyphus* sp.) was reported by Dietz as heavily infesting the dust from the carrying belts in a large grain elevator at Beech Grove.

Powder post beetles (*Lyctus* sp.) were reported destructive to building timbers at Seymour, Hartford City, Nappanee, Columbus, Vevay and Albion, Russellville and also to spade handles.

HOUSEHOLD AND MISCELLANEOUS PESTS.

Clothes moths (*Tinea pellionella* L.), common carpet beetles or "buffalo bug" (*Anthrenus scrophulariae* L.) and the black carpet beetle (*Attagenus piceus* Oliv.) were reported frequently as damaging clothing, carpets and stuffed furniture. The cigarette beetle (*Lasioderma serricorne* Fab.) was also commonly reported infesting homes, having developed in the filling of stuffed furniture.

Silverfish (*Lepisma saccharina* L.) was common throughout the summer in apartment houses and other dwellings in Indianapolis according to H. F. Dietz. In apartment houses, according to Dietz the insects seemed to prefer the incinerator shutters and from this source invaded the apartments. Inquiries reporting damage to walls, and house furnishings, including rugs, drapes and doilies were received during June, July and August from Elnora, Nappanee, Lafayette and Monon.

Ants were annoying and destructive as usual throughout the state, especially in lawns and houses but occasionally in bee hives and attacking melon seed.

Crickets (*Gryllidae*) were reported sufficiently abundant to be annoying in a house at Lafayette in April.

Bedbugs (*Cimex lectularius* L.) were reported from all sections of the state. One report from Rockville noted their unusual prevalence in poultry houses.

Mosquitoes (*Culicidae*) were reported very abundant at Muncie and Indianapolis in June.

Saddle back caterpillar (*Sibine stimulae* Clem.) was reported the last of August and early September from Greensburg, Liberty and Westport. At the later place they were feeding on sycamore. In other cases it was reported because of its irritating hairs.

Cat and dog flea (*Ctenocephalus canis* Curt.) was normally abundant, many reports being received. Definite reports were received from Burnettsville, Crawfordsville, Culver, Evansville, Fountain City, Ft. Wayne, Gary, Indianapolis, Jeffersonville, Lafayette, Milford, Morocco, Mt. Vernon, Plainfield, Richmond, Tell City, and Troy. The infestations were in dwellings and especially in barns and other farm outbuildings. Two reports referred to lawn infestations.

Termites (*Reticulitermes flavipes* Koll.) were troublesome throughout the state as for the past several years. Reports included the following counties: Blackford, Cass, Clinton, Delaware, Grant, Hamilton, Lake, Laporte, Lawrence, Marion, Montgomery, Morgan, Noble, Putnam, Tippecanoe, Union, Vanderburgh and Wayne.

The feather mite (*Liponyssus silvarium* C. and F.) was abundant and destructive to poultry at Ft. Wayne and Oxford.

NOTES ON BIRDS OF LAKE MAXINKUCKEE REGION.

SAMUEL E. PERKINS, III, Indianapolis.

Messrs. B. W. Evermann and H. W. Clark made a very comprehensive report on the birds of Lake Maxinkuckee Region covering the period from 1899 to 1913.¹ During the last ten years certain changes in bird life about the lake have been observable. A number of the birds have become rarer while others have become common which previously have been reported scarce. Twenty-two new species are added to the list of those found by Evermann and Clark, which brings the total number of species of birds seen near Lake Maxinkuckee to 197. In many instances I have been able to add nesting data not included in the report. The number of cottages about the lake as shown by the detail map dated 1900 attached to the report of Evermann and Clark is 99. There are now (1927) 180 cottages.

Norris Inlet and Green's Marsh remain almost as they were during the period covered by Evermann and Clark. Farrar's Woods on the southwest shore is as woody but has been taken over by camping parties during most of the summer months for some years, so that bird life is not as representative there as formerly. Cottages border the lake on most of its shoreline now, causing some additional disturbance to the normal activities of shore birds.

These notes are supplemental to the above named report and cover the period from 1922 to 1927, inclusive.

Sterna antillarum. Least tern.² In 1910 Mrs. Elizabeth C. Marmon of Indianapolis, reports she saw this tern on her pier.

Mergus serrator. Red-breasted merganser. A dozen in a flock passed along the east side of the lake on Apr. 4, and on July 23, 1927, two were seen and the next day one was watched in the lake opposite the gravel pit.

Ixobrychus exilis. Least bittern. Not observed at any location except Norris Inlet. Two young were found just out of the nest on July 18, 1926, when four adults were also seen.

Rallus elegans. King rail.² On July 3, 1927, in the shallow stream running through Norris Inlet, just north of the road south of the lake, there came out of the cress beds a king rail and two half-grown black-feathered young.

Rubicola minor. Woodcock. The woodcock continues to be very rare in my experience about this lake. My only notes are of three immature birds with parents seen May 30, 1925, in Farrar's Woods.

¹Pub. No. 7, Dep. Conserv. St. Ind., 1920.

²Indicates species not included in Evermann and Clark report.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

Tringa solitaria solitaria. Solitary sandpiper.² Mrs. E. C. Marmon says she occasionally sees this bird along her beach.

Oxyechus vociferus. Killdeer. My earliest and latest nesting dates are as follows: May 30, (1925), nest and eggs; July 20, (1925), nest and eggs. There are no nests on the few gravel bars. Nests were found in fields.

Colinus virginianus virginianus. Quail. This bird is apparently holding its own. A nest was found with a dozen eggs on July 20, 1925, and another on May 30, the same year, containing two eggs.

Tympanuchus americanus americanus. Prairie chicken. Rare. I saw two cross the road near Kewanna in the summer of 1924, and Capt. Chas. Hulsburg reported four seen west of the lake in June, 1927.

Zenaidura macroura carolinensis. Mourning dove. My earliest and latest nesting dates are April 19, (1924), four nests with two eggs each; July 30, (1923), nest of fledglings (one of this clutch was reported by Biological Survey as killed at Jonesboro, Louisiana, in Jan., (1927); Aug. 9, (1924), building nest.

Nyctea nyctea. Snowy owl. There was a great southern migration of these birds in winter of 1926, which included northern Indiana. The only report of one near Lake Maxinkuckee was of the killing of one at Fulton, Dec. 6, some miles south of the lake. Several were taken at Indianapolis in January, 1927.

Coccyzus erythrophthalmus. Black-billed cuckoo.² Not positively identified till July 23 and 24, 1927, when it was stalked in the woods north of Vonnegut's orchard.

Archilochus colubris. Ruby-throated hummingbird. A pair was found nesting with fledglings about ready to leave the nest in the woods northeast of Marmon's, Aug. 23, 1926. The nest was saddled in a maple toward the tip of the branch about 15 feet up.

Tyrannus tyrannus. Kingbird. I found a nest in Vonnegut's orchard, June 8, 1922, with young and at the same time and place in 1924, with eggs. On July 20, 1925, a nest and three young a week old were climbed to in a sycamore at water's edge near Aubeenaubbee Creek.

Sayornis phoebe. Phoebe. My earliest and latest nesting dates are April 4, (1927), nest ready for eggs; June 28, (1924), four young in nest (one of these fledglings, No. 143870, was found dead at Zolle, Louisiana, in Jan., (1926); July 20, (1922), nest and three young.

Myiochanes virens. Wood pewee. Pairs have been observed in Farrar's Woods, near Maxinkuckee Landing, and in the woods north of Vonnegut's orchard. A nest in Farrar's Woods was saddled at the juncture of three limbs with young in it about three days old, on July 22, 1927. It was 20 feet up in a cottonwood.

Empidonax virens. Acadian flycatcher.² This bird does not appear to be common. While in company with Mr. Alden H. Hadley we came across the acadian flycatcher in the woods north of Vonnegut's orchard, where there is a high heavy canopy of forest with light underbrush, on July 20, 1925. In the same woods it was found July 29, 1927.

Otocoris alpestris praticola. Prairie horned lark.² This bird has been seen singly on June 20, 1925, east of the lake about a half mile.

Also, in the road where our auto approached to within 15 feet of it as it pecked at food, it was seen Feb. 1, 1927. It was under observation for several minutes. Two were seen again east of the lake on Apr. 4, 1927. Twelve seen south of lake Oct. 30, 1927.

Cyanocitta cristata cristata. Blue jay. Found nests as follows: July 9, (1922), with young birds at Spangler Creek and again there in June, 1925; July 20, (1922), young in nest east of Marmon's near the lake shore in a vine.

Dolichonyx oryzivorus. Bobolink. It is breeding at the Inlet. Observed at the Inlet May 29, 1925, May 28 and July 4, 1926. During this summer (1927), at least five pairs had nests in the grass west of the branch which flows through Norris Inlet.

Molothrus ater ater. Cowbird. I have found it laying its eggs in the nest of a song sparrow (May 28, 1926), and on July 5, the same year, gathered the nest of a yellow warbler containing three eggs of a cowbird only. July 5, 1927, a chipping sparrow was sitting on three of her eggs and one cowbird egg. All these were in the Vonnegut's orchard and an adjoining field northeast of the lake.

Icterus spurius. Orchard oriole. Found nesting in Vonnegut's orchard with young hatching, June 5, 1922, and a pair feeding young several days out of the nest on the edge of Norris Inlet, July 3, 1927.

Icterus galbula. Baltimore oriole. This oriole now nests abundantly on the northeast side of the lake, especially along the lake road from Aubeenaubee Bay to Maxinkuckee Landing. I found nests June 8, (1922), with young; July 3, (1927), with young which left the nest that day.

Astragalinus tristis tristis. Goldfinch. Found nest of this species July 20, 1925, with three eggs, in a small elm north of the Academy Artillery building.

Zonotrichia albicollis. White-throated sparrow. May 30, 1925, one was seen on the ground feeding at the foot of trees. Glasses revealed that it had a large lump the size of a pea on the head above one eye, otherwise it appeared normal. It was stalked for some time at close range. Could fly and hop and eat and seemed in good flesh.

Spizella passerina passerina. Chipping sparrow. This bird has become more than "fairly common." My notes show nesting dates May 30 (1925), nest and eggs; July 22 (1927), nest with two eggs and one cowbird egg.

Spizella pusilla pusilla. Field sparrow. It was found breeding May 28 (1926), nest and three eggs; July 3 (1927), nest and three eggs.

Melospiza melodia melodia. Song sparrow. Song sparrows have been found nesting on the following dates: May 28 (1926), nest containing three fledglings and one cowbird; July 28 (1923), nest and young.

Cardinalis cardinalis cardinalis. Cardinal. Common now in Farrar's Woods and in the woods pasture north of Vonnegut's orchard. Feb. 1, 1927, two flocks of a dozen each (males) were found in pawpaw thickets north of the lake. A nest and three eggs was located May 28, 1926.

Zamelodia ludoviciana. Rose-breasted grosbeak. Rare. On June 10, 1923, the nest was found near the east side road south of Maxinkuckee Landing. It was up 10 feet in a sapling and contained four eggs.

Piranga erythromelas. Scarlet tanager. They were nesting July 21, 1925, near east side road.

Progne subis subis. Purple martin. A pair or two are reported by Evermann and Clark principally at the south end of the lake. During 1924 and subsequent years several large colonies have been established near the road where it borders the lake south of Long Point where many colony nesting boxes have been erected and maintained for their use. At least a dozen pairs breed here yearly. Another colony almost as large is housed in boxes at a farm house near the juncture of the south and west roads nearest the lake, south of Farrar's Woods.

Petrochelidon lunifrons lunifrons. Cliff sparrow. This species, out the summer of 1899 and from September 9 to 24 in 1913," has become rare. I have not found any breeding colonies about the lake. The birds have not been seen since 1922 nearer than Mexico, Ind., about 25 miles south, where on June 23, 1923, there were seven gourd-shaped nests under the eaves of a large barn. The colony was not back in 1924, and efforts to locate it or any other nearby have been unavailing.

Riparia riparia. Bank swallow. The largest colony reported by Evermann and Clark as at the gravel pit is still located there (90 holes in 1927). Another colony of 40 nests is located half a mile east on the Maxinkuckee road. They have been found nesting May 30 (1921), nests with young and with eggs; July 30 (1927), all young out of nests and on wires above colony.

Stelgidopteryx serripennis. Rough-winged swallow. While not so numerous as the bank swallow it is common. I have found it nesting May 28 (1926), nest and eggs, and on July 4 (1926), four young in nest. Five fledglings were dug out by myself and Mr. Frank M. Woodruff. True to the species' solitary habit, it was a lone nest in a long sand bank three feet high, dug five inches below the grassy surface to a depth of two feet. In most cases I find these birds using empty tile drains where same are two feet or more above the water surface. Many in drain openings are mostly composed of much more grass than is used by the bank swallow. The usual depth at which the nest is placed is two feet.

Lanivireo flavifrons. Yellow-throated vireo. Seen and heard in the woods north of Vonnegut's orchard July 20, 1925, and near same place July 23, 1927. Found several in Farrar's Woods on July 30, 1927. I think it breeds there.

Vireo griseus griseus. White-eyed vireo.² Upon the authority of Mrs. E. C. Marmon, this species is included. She says "the red-eye nested in the yard in the early years but is now supplanted by the white-eye, an agreeable exchange."

Protonotaria citrea. Prothonotary warbler.² June 28, 1925, a single male was seen alongside the fence in Green's Marsh. It played about in the lower branches of a willow tree while under observation. Mrs.

E. C. Marmon reports that in 1911 a pair nested near the Chas E. Coffin place.

Dendroica aestiva aestiva. Yellow warbler. Nest and three eggs found five feet up in a catalpa east of the lake, June 10, 1923. Nest and two eggs May 28, 1926, in Vonnegut's orchard. On May 29, 1926, a nest being built was observed east of Vonnegut's orchard in a briar patch. When visited again June 5, it contained three cowbird eggs only and was found to be abandoned on later trips. No attempt was made in this instance to cover the cowbird eggs.

Dendroica cerulea. Cerulean warbler.² This species nested in late May, 1910, in the Vonnegut's woods high in a forest tree, reports Mrs. E. C. Marmon.

Dendroica castanea. Bay-breasted warbler. This species reported by Mrs. E. C. Marmon.

Dendroica fusca. Blackburnian warbler. Observed by Mrs. Marmon during the migration wave of 1909.

Dendroica discolor. Prairie warbler.² Mrs. Marmon reports several of these birds came through her estate at the lake during the unusual warbler migration of 1909.

Seiurus motacilla. Louisiana water-thrush.² Mrs. Marmon reports that up to about 1922, several were seen each year but she has not recorded it since.

Icteria virens virens. Yellow-breasted chat.² Included on the authority of Mrs. Marmon.

Wilsonia pusilla pusilla. Wilson's black-cap.² Included on the authority of Mrs. Marmon who reports having listed it in 1909 and 1911.

Wilsonia canadensis. Canada warbler.² The Canadian warbler was observed one time on May 28, 1926. This species was also recorded by Mrs. Marmon.

Mimus polyglottos polyglottos. Mockingbird.² The mockingbird has been observed on two occasions. June 23, 1923, two were seen to fly from telephone wires ahead of us to a clump of trees at the north edge of a field a short distance away. This was about three miles east of the lake on the Mentone road. May 29, 1925, one was seen in Vonnegut's orchard.

Dumetella carolinensis. Catbird. Nesting records: June 9 (1924), four fledglings in nest; July 20 (1925), nest and one fledgling.

Toxostoma rufum. Brown thrasher. June 9, 1924, nest and four young was found.

Thryothorus ludovicianus ludovicianus. Carolina wren.² On July 3, 1927, I followed a Carolina wren from the Vajen cottage on the east side road to the barn back of Rector's house at Maxinkuckee Landing. I heard it sing repeatedly but could not see it. On the afternoon of July 23, I stalked it as it sang in a large vine-covered tree over the barn at Rector's. Called Mr. Rector, who said the species had been about his premises in summer for six or seven years.

Thryomanes bewicki bewicki. Bewick's wren.² On May 29, 1925, I found this wren at Leiter's Ford five miles south of Maxinkuckee on

the Tippecanoe River. On July 22, 1927, I distinctly heard it sing its song in the woods north of Vonnegut's orchard.

Troglodytes aedon aedon. House wren. From a "not very common" summer resident up to 1913, it has gained in numbers and is now very numerous. In summer one is not out of hearing of the song of this bird at any part of the lake shore. This may be due in part to the placing of rural mail boxes in front of houses which serve as nest boxes. I have as earliest and latest nesting dates: May 29 (1925), nest and eggs; Aug. 3 (1927), nest and two eggs.

Cistothorus stellaris. Short-billed marsh wren.² The short-billed marsh wren is present at the Outlet and Inlet, but in different sub-habitat therein from the long-billed. I found the empty nest of it at the Outlet in the grass at a place where there was no water below it and where no cattails grew for 50 feet in any direction. In the south half of the Inlet on July 30, 1927, I approached within 25 feet of two males as they sang. Many of these birds have a different habit from long-billed in that they fly some distance to another stalk, when approached, where they again sing instead of at once dropping out of sight in the cattails or grass upon being disturbed. Apparently the two species of marsh wrens do not nest near each other even where suitable areas are close. It is easily a quarter-mile between the places where the two species were observed at the Inlet.

Telmatodytes palustris iliacus. Prairie marsh wren. Found to be most numerous in the north half of Norris Inlet and at the marsh west of Green's Marsh. Many nests were found each place in 1926 and 1927. All the nests of this species were found over water and at such place that cattails were growing for some distance every direction from the nest. On July 4, 1926, a nest with two chocolate-brown eggs in it was found at the Inlet. Three other empty nests were observed. The same day, in another part, were five empty nests. In 1927, I found on July 3, four pairs at the Inlet and one nest and one pair of birds at the Outlet. A nest with five fledglings almost two weeks old was found at the Inlet July 23, 1927. This nest was built in the tall grass over water among cattails.

Penthestes atricapillus atricapillus. Black-capped chickadee. The black-capped chickadee built a nest in a tree near the east side road and raised a brood of three which left the nest June 24, 1924.

Hylocichla mustelina. Wood thrush. It was often heard during the summer and was found nesting near east side road in an elder bush with one young and two eggs, June 14, 1925.

Hylocichla fuscescens fuscescens. Veery.² This species was found nesting by Mrs. Marmon in a bush about 500 feet north of the Marmon cottage, in 1908.

Planesticus migratorius migratorius. Robin. Earliest and latest dates are April 19 (1924), nest and two eggs; Aug. 1 (1923), nest and young.

SUMMER RESIDENT BIRDS OF TURKEY RUN STATE PARK.

FREDERICK H. TEST, West Lafayette.

Turkey Run, the largest of Indiana's state parks, is located in Parke County about ten miles from Rockville, and three miles from Marshall. The park consists of approximately 925 acres stretching along either side of Sugar Creek for a distance of two miles. Almost all of this area is heavily forested except near the hotel, Lusk Homestead, and parts of the new tract of 157 acres where the woods are very open. Part of this is virgin timber and part second growth. Sugar Creek, a stream about 45 yards wide, and three or four small tributaries run through the park, but there are no swamps. Because of the extensive woods not as large a variety of birds was found as if it had been interspersed with open fields. The park is much cut up, especially at the lower end, by deep gulches and canyons through which run small streams. The walls of these canyons are of sandstone and in some places are nearly 100 feet high. Excellent cover is afforded in many parts of the park by the thick underbrush made up principally of dogwoods, witch-hazel, sassafras, spice-bush, papaw, leatherwood and berry bushes. Along the top of the river bank and the rims of the canyons are stands of hemlock and American yew, while the rest of the high ground is covered with oaks, maples, hickories, beeches, walnuts, tulips, and many other less common species. On the lowlands along the river sycamores, lindens, box elders, elms, and walnuts are the common trees.

Although protection is given birds and other forms of wild life by forbidding shooting and trapping in the park and by effectively disposing of stray cats and dogs, the great number of visitors frighten the birds somewhat so that not many species are seen when large groups are on the trails. The dense woods furnish an abundance of food for insect-eating birds including five species of woodpeckers. Over and along the river there is a plentiful supply of food for swallows, swifts and flycatchers, and the fish in the river support two pairs of kingfishers. There is not much attraction for marsh and shore birds nor for pasture-loving birds, although many were seen near the park. Spotted sandpipers were seen only a few times and kildeer were not as common as might be expected. The absence of two birds, the bronzed grackle and the brown thrasher, was very noticeable. Only one of the former was seen in the park, flying near the hotel, and the latter was not once recorded in the park, but both were seen occasionally within a few miles of Turkey Run. Probably the two most common birds were the wood thrush, heard abundantly during the day, and the whip-poor-will, whose song was very much in evidence at night. Although not

found in the heavily wooded sections, the chipping sparrow was the common bird near the hotel, several nests being found. These sparrows were very tame and would hop between our legs and under our chairs with no signs of fear while we were sitting in front of the tent. The rarest bird at Turkey Run was the bald eagle, which was observed only once by Mr. Esten and Otto Behrens, Jr., while on Trail No. 3. Mr. Elam, the superintendent of the park, reported that he had seen an eagle in the park several times during the three or four preceding years. Another rather rare bird was the Louisiana water-thrush, seen frequently in the deep woods along a stream up Newby Gulch. We were quite surprised to find a number of cerulean warblers nesting in the park. On one trip six or eight were seen and they also were seen at other times. Summer tanagers were seen occasionally, so it is safe to assume there were one or two pairs nesting in Turkey Run. We were told that several years ago a covey of pheasants had been liberated, but although we watched for them, none were seen.

These observations, extending over the period from June 20 to September 9, 1927, were made by Sidney R. Esten, Otto Behrens, Jr., and the writer while acting as nature guides at Turkey Run for the Department of Conservation.

The following list includes 68 species positively identified and a supplementary list of 7 species the identity of which was not confirmed or whose range seemed to include the park.

190. *Botaurus lentiginosus*. American bittern. Rather rare. Seen only once or twice on Trail 3 by Otto Behrens, Jr.

194. *Ardea herodias*. Great blue heron. Rare. Seen a very few times flying over the park.

201. *Butorides virescens*. Green heron. Frequently seen, especially near the river.

228. *Philohela minor*. American woodcock. Uncommon. Observed only once or twice on Trails 1 and 8 where the ground was moist.

263. *Actitis macularia*. Spotted sandpiper. Not common. Seen a few times on bars along the river.

273. *Oxyechus vociferus*. Kildeer. Frequently found in a field back of the garage and also seen flying over the park.

289. *Colinus virginianus*. Bob-white. Frequent throughout the park.

316. *Zenaidura macroura carolinensis*. Mourning dove. Common, especially near the hotel.

325. *Cathartes aura septentrionalis*. Turkey vulture. Common throughout the park. As many as nine were seen circling together over the woods at one time.

331. *Circus hudsonius*. Marsh hawk. Not common. Seen on Trail 1 and occasionally elsewhere.

333. *Accipiter cooperi*. Cooper hawk. Not common. Seen a few times on Trail 4.

337. *Buteo borealis*. Red-tailed hawk. Frequent. Seen on Trail 4 and near Boulder Canyon.

352. *Haliaeetus leucocephalus*. Bald eagle. Rare. Seen only once during the summer by S. R. Esten and Otto Behrens, Jr., while on

Trail 3. Mr. Elam, the superintendent of Turkey Run, reported that he had seen an eagle in the park several times during the four or five preceding years.

373. *Otus asio*. Screech owl. Common. Heard on most of the trails and around the hotel.

375. *Bubo virginianus*. Great horned owl. Frequent. Found on both sides of the river.

387. *Coccyzus americanus*. Yellow-billed cuckoo. Common on all the trails.

388. *Coccyzus erythrophthalmus*. Black-billed cuckoo. Uncommon. Seen on Trails 1, 3 and 7.

390. *Ceryle alcyon*. Belted kingfisher. Common along Sugar Creek. Probably there were at least two pairs that nested in or near Turkey Run, although no nests were found.

393. *Dryobates villosus*. Hairy woodpecker. Frequent. Seen on Trails 4 and 8.

394. *Dryobates pubescens medianus*. Downy woodpecker. Fairly common and seen on most of the trails.

406. *Melanerpes erythrocephalus*. Red-headed woodpecker. Common. Seen on some of the trails but more common near the hotel and in the open.

409. *Centurus carolinus*. Red-bellied woodpecker. Frequent. Several pairs with young were noticed near the hotel and also in deeper woods.

412. *Calaptes auratus*. Flicker. Common. Seen throughout the park.

417. *Antrostomus vociferus*. Whip-poor-will. Heard abundantly all through Turkey Run, although only two or three were seen.

423. *Chaetura pelagica*. Chimney swift. Common. Seen flying over the hotel and also the woods.

428. *Archilochus colubris*. Ruby-throated hummingbird. Frequent. Seen several times, but no nests were found.

444. *Tyrannus tyrannus*. Kingbird. Not common in the park. Seen frequently along the roads near the park.

452. *Myiarchus crinitus*. Crested flycatcher. Fairly common. Seen on all trails.

456. *Sayornis phoebe*. Phoebe. Common along the river and in the canyons. Several nests were found built on the rock of the canyon walls.

461. *Myiochanes virens*. Wood pewee. Common all through the park. A few nests were found.

465. *Empidonax virens*. Acadian flycatcher. Common, especially along the river. Four or five nests were found on Trail 1.

477. *Cyanocitta cristata*. Blue jay. Common. Seen on most of the trails.

488. *Corvus brachyrhynchos*. American crow. Common. Seen in most parts of the park.

495. *Molothrus ater*. Cowbird. Seen frequently near the hotel. One young cowbird followed a pair of chipping sparrows around near the hotel for several days, being fed by them.

501. *Sturnella magna*. Meadowlark. Common in fields back of the garage but in no other place in the park except the new 157-acre tract. Common outside the park.

507. *Icterus galbula*. Baltimore oriole. Frequently seen and heard during first and latter part of summer, but they were silent during the latter part of July and the first two weeks in August.

511b. *Quiscalus quiscula aeneus*. Bronzed grackle. Rare in park. Seen only once, flying over the hotel, but observed several times within a few miles of Turkey Run.

529. *Astragalinus tristis*. American goldfinch. Frequent. Seen frequently flying over hotel and along Sugar Creek.

Passer domesticus. English sparrow. Common around hotel. Several nests were built under the hotel porch roof.

560. *Spizella passerina*. Chipping sparrow. Abundant near the hotel. These birds were very tame, picking up crumbs within a few inches of us. Several nests were found. Seen only near hotel and in the camp grounds.

563. *Spizella pusilla*. Field sparrow. Frequently seen and heard in the fields of the park. One nest was found on Trail 2.

581. *Melospiza melodia*. Song sparrow. Frequent. Seen mostly along the river.

587. *Pipilo erythrophthalmus*. Towhee. Common. Observed on Trails 2, 3, 4 and 8.

593. *Cardinalis cardinalis*. Cardinal. Frequently seen on all trails. One nest was found on Trail 1 about six feet from the ground in a small elm which stood just at the side of the trail over which hundreds of people passed while the young cardinals were in the nest.

598. *Passerina cyanea*. Indigo bunting. Frequent. Seen on Trails 2 and 3 and just outside the park.

608. *Piranga erythromelas*. Scarlet tanager. Frequent. Seen on Trails 2 and 3.

610. *Piranga rubra*. Summer tanager. Rare. Seen several times at the same place on Trail 2, a rather open space. Probably one pair nested in the park.

611. *Progne subis*. Purple martin. A colony of four or five pairs of martins shared with some English sparrows a dilapidated martin house erected in the field back of the garage.

613. *Hirundo erythrogastra*. Barn swallow. Seen several times flying near the garage and along the river near the covered bridge.

616. *Riparia riparia*. Bank swallow. Common along Sugar Creek. Nested in holes in the sandstone walls of the canyons.

617. *Stelgidopteryx serripennis*. Rough-winged swallow. Frequent along Sugar Creek. Nested with bank swallows in holes in the canyon walls.

619. *Bombycilla cedrorum*. Cedar waxwing. Frequent around the hotel, where they feasted on bush honeysuckle berries. No nests were found but two evidently deserted young cedar waxwings found on the ground were raised by Mrs. Esten and finally released.

624. *Vireosylva olivacea*. Red-eyed vireo. Frequent on all the trails. One nest was found on Trail 4.

627. *Vireosylva gilva*. Warbling vireo. Common on all trails. No nests were found.

658. *Dendroica caerulea*. Cerulean warbler. Frequent. Although we found no nests, probably several pairs nested in Turkey Run.

674. *Seiurus aurocapillus*. Oven-bird. Frequently heard on Trails 2 and 3.

675. *Seiurus motacilla*. Louisiana water-thrush. Frequently seen and heard on Trails 2 and 4.

681. *Geothlypis trichas*. Maryland yellow-throat. Not common, although one nest was found in a clump of weeds growing in a small plot of damp ground on Trail 4. Seen also on Trail 2 along the river.

683. *Icteria virens*. Yellow-breasted chat. Rare. Seen only once on Trail 2 by the writer.

687. *Setophaga ruticilla*. American redstart. Frequently seen on several of the trails, especially 2 and 3. No nests were found.

704. *Dumetella carolinensis*. Catbird. Seen frequently on Trails 1 and 2 and around the hotel, but no nests were found.

718. *Thryothorus ludovicianus*. Carolina wren. Common. Seen on most of the trails, but especially common along Sugar Creek and up Newby Gulch.

721. *Troglodytes aedon*. House wren. Rare. Only one pair, which probably nested near the Hockett home, was seen.

727. *Sitta carolinensis*. White-breasted nuthatch. Common throughout the park and especially near the hotel and camp grounds.

731. *Baeolophus bicolor*. Tufted titmouse. Common, especially in the camp grounds and around the hotel, but also seen on most of the trails. One of the men on the park patrol usually shared his lunch with a tufted titmouse which flew down to the table where he had his food spread.

735. *Penthestes atricapillus*. Black-capped chickadee. Frequent. Seen on Trails 1 and 2 and around the hotel.

755. *Hylocichla mustelina*. Wood thrush. Abundant all through the park. Probably the most common bird at Turkey Run. Several nests were found.

761. *Planesticus migratorius*. American robin. Common around the hotel and camp grounds. Several nests were found.

766. *Sialia sialis*. Bluebird. Frequent around hotel and back of garage.

SUPPLEMENTARY LIST OF BIRDS NOT POSITIVELY IDENTIFIED OR
OBSERVED ONLY OUTSIDE THE PARK.

360. *Falco sparverius*. Sparrow hawk. Seen several times within a mile or two of the park but never in it.

368. *Strix varia*. Barred owl. We thought we heard the hooting of this owl but it possibly was that of the great horned.

467. *Empidonax minimus*. Least flycatcher. A flycatcher was identified as this species but may have been an acadian.

540. *Poocetes gramineus*. Vesper sparrow. Seen in fields just outside the park and probably occurred in Turkey Run.

622. *Lanius ludovicianus*. Loggerhead shrike. Seen frequently within two or three miles of Turkey Run but never in the park.

639. *Helmitheros vermivorus*. Worm-eating warbler. Otto Behrens, Jr., and the writer identified a bird on Trail 3 as this species but the identification was not positive and no others were seen during the remainder of the summer.

703. *Mimus polyglottos*. Mockingbird. One was observed about ten miles from Turkey Run near the "Shades."

THE OCCURRENCE OF THE STARLING AT WEST LAFAYETTE, INDIANA.

LOUIS AGASSIZ TEST and FREDERICK H. TEST, West Lafayette.

The starling, *Sturnus vulgaris*, was first successfully introduced into the United States in 1890, when 80 birds were released in Central Park, New York. Since that time they have spread rapidly over the eastern states and are gradually extending their range westward. Cooke stated that the breeding range in 1922 extended as far west as eastern Ohio. In 1925 birds had been reported at Ann Arbor, Mich.; Milwaukee, Wis.; and Urbana, Ill. While this range would seem to include Indiana, no starlings had been reported from this state at that time.

Some time during the winter of 1925-26, Dr. Stanley Coulter received a letter from Mr. Amos W. Butler stating that he had been informed by the U. S. Biological Survey that the starling had been reported from West Lafayette. This letter was handed to us with the request that we investigate the report. Diligent inquiry failed to show any grounds for such a report. However, Cooke's bulletin issued in 1925 stated that the first occurrence of the starling west of the Alleghany Mountains was at West Lafayette, Ohio, and it is possible that this town was confused with West Lafayette, Indiana.

On the early morning of May 12, 1926, two starlings were seen by us in a partially dead elm in the yard at 629 Russell Street, West Lafayette, and were watched for some minutes. As far as we are able to learn, this is the first report for this vicinity. These two birds seemed to be disputing the right of a pair of red-headed woodpeckers to certain holes in the tree.

No more were seen until October 31, 1926, when another was seen in the same tree at 629 Russell Street, and again two more on November 2, which suggested the possibility that the birds may have nested there.

January 1, 1927, two starlings were seen at the Opp farm, one mile south of town on the River Road. About the same time Mr. Scipio, living six miles south of West Lafayette on the same road, reported to Dean M. L. Fisher that a flock of about 20 blackbirds had been roosting in his barn for some time. Investigation on January 4, 1927, proved the birds to be starlings and skins were made from two specimens which had been picked up dead that morning. The birds remained at the Scipio farm all spring and summer and in May were found nesting in the oaks near the house, where at least one nest with eggs was found. Red-headed woodpeckers were nesting in the same tree.

Some starlings are usually seen whenever the Scipio or Opp farms are visited. The birds usually are absent most of the day, leaving in

the early morning to return to the farms at evening. They were seen by us as late as October 30, 1927, and Mr. Scipio has since stated that every morning and evening they gather in the oaks near his house.

On March 9 and again on March 30, 1927, starlings were seen in our yard at 511 Russell Street, two birds being seen each time.

While the starlings have not been reported from other parts of the county, they seem to have established themselves in this locality and will no doubt soon spread over much of this section. It will be interesting to note what effect they have upon the native wild birds. They have not been observed flocking with any other species and when seen have usually been single or in small groups and appeared quite shy. So far, they seem to be confined to the open country and to avoid the town. Russell Street is at the western edge of West Lafayette, with open country beyond.

THE STARLING IN MADISON COUNTY, INDIANA.

MRS LOUISE S. SWAIN, Pendleton.

Since the successful introduction of the English starling into America on March 6, 1890, when 80 of these birds were liberated by Mr. Eugene Scheiffelin at Central Park, New York City, ornithologists have viewed with apprehension their increase and spread. That they have come as far west as Indiana we have numerous reports to convince us; that they have taken up their abode in Madison County, Indiana, with the purpose of becoming permanent residents, the following experience of the writer will prove.

Last February 20, a friend interested in birds, living 1½ miles northwest of Pendleton, told me of a strange bird which had appeared repeatedly with a flock of English sparrows and fed with them on her driveway quite near the house. She described the bird as "larger than the sparrows, dusky gray in color, a walker, with a long, sharp bill and very short tail." Several times following this date she mentioned the continued presence of this strange bird on her premises until on the morning of April 4 she called me to say there were two of these birds, exactly alike, their bills yellow, their shiny, iridescent feathers somewhat speckled with light creamy buff, walking about the barn lot with much assurance, making frequent trips to the decayed top of a beech tree in a woodlot opposite her home.

I went out at once to see these two strangers and identified a pair of starlings busily stripping the dried blades from stalks of corn fodder lying about the barnlot. Each bird was actively engaged in this pursuit and use of the glasses easily revealed a flicker hole on the north side of the beech tree, at least 30 feet from the ground, into which the starlings were carrying the nesting material. At daylight the following morning this pair of birds was industriously prodding with their long, sharp bills into the sod of a pasture lot near the house for their breakfast, all the while keeping very close together. If by chance one worked more rapidly than the other, thus getting a few feet ahead, the one in front would pause, look back and wait until the mate caught up before proceeding further with the hunt for food. I spent the entire forenoon of April 5 observing the activity of these birds and was convinced we were to have a starling brood ere long.

May 18 much activity on the part of the pair of starlings suggested the feeding of fledglings, and about 1 p. m. the parent birds escorted six fully fledged babies, quite as able to fly as were the parents, to an apple orchard in front of the house, where it was possible to observe the feeding of the babies in response to their persistent, raucous calls for food.

The farmer on whose premises these starlings were hatched shot five of the babies and one adult on the afternoon of May 18. The skins of one baby and one adult were prepared for the report of the Indiana Audubon Society's convention at Newcastle on May 19. Mr. Sidney Esten prepared these skins and they are now in his possession. Another of the babies was presented to Dr. Amos W. Butler, a third to Mr. Samuel E. Perkins, and the two remaining were too badly torn with shot to permit their preservation.

A second pair of starlings had appeared in this same woods about two weeks before the brood of the first pair was brought from the nest. In preparation of the adult skin it was revealed that this bird was a female with a fully developed egg, light blue in color, which in all probability would have been laid that day, also five other eggs in various stages of development. I saw four starlings fly from the nest-hole after these six were killed, in all probability three adults and the remaining one of the brood of six. The development of eggs in the one adult which was killed would suggest this bird was the female of the second pair. These birds were observed by Mr. Sidney R. Esten of Pendleton, Dr. Earl Brooks of Noblesville, and Otto Behrens, Jr., of Anderson, during their nest building activities.

On June 8, 1927, I went with Mr. Esten in response to a call from Anderson, Indiana, to see some starlings which were reported there. We drove out the East Twelfth Street road toward State Road 67, and found six nests occupied by starlings in our two hours of observation. All these nests were in telephone poles on the south side of the road except one, which was in the south side of the pole on the north side of the road. We saw nine starlings, eight adults, one immature; parents carrying food into three nest-holes, while from each of three other nest-holes the head of an adult looked inquiringly at us. The average height of these nest-holes from the ground was about 13 feet. One nest, however, was easily reached by standing on a fence post; the bottom of the nest must have been 12 or 15 inches below the opening, as it was not possible to reach it by thrusting the arm into the hole.

A fitting close to this the first chapter in the history of the starling in Madison County is the following: On Thanksgiving day, November 24, 1927, Mr. Luther Day, a farmer living six miles due north of the woods in which the starling brood was hatched in May, went into his haymow at dusk to catch pigeons. While thus engaged, a strange bird flew directly toward his face, which he was able to catch and take into his home for identification. It proved to be a starling whose winter coat is beautifully metallic in shades of purple, green, rose and bronze. The tip of each feather bears its triangular marking of creamy buff, the bill is horn color, while the keen, bright eyes do not miss a motion of those who are eager to observe this stranger who has taken up his abode in our midst. This starling was brought in an ordinary bird cage to my home November 25, where it was later presented to Mr. Esten, who now has it and reports it is quite rapidly becoming tame, even eating flies and hamburger from Mrs. Esten's hand. It eats some grain, bathes frequently, enjoys the swing in a large cage which it now occupies, and is in a general way adapting itself to its new environment.

To those who wonder what the status of the starling in Indiana may be five years hence I quote the following from the experience of Mrs. Mable Osgood Wright of Connecticut, who says: "Here in Connecticut starlings were not conspicuous until 1900, but now they are a serious menace both to the summer resident birds, whose nesting sites they appropriate, and to the winter food supply of our most beneficial resident birds.

"Personally I have been watching the habits of the starlings as individuals and in flocks for the past five years, limiting myself to a two-mile radius of home, and I am appalled at the injury they inflict, both upon birds, for the starling is a great fighter armed with a strong bill, and on tree and bush fruits.

"Beginning to mate as early as February, the starlings of Birdcraft Sanctuary and my own place often raise two broods a year, it being quite usual to see the first brood following the parents about, clamoring for food, while they are busy with the second brood.

"When the second family is on the wing, the two broods with the parents form a family flock in early June, when they spend the time in visiting cherry trees, berry bushes, and grain fields until August, when the general flocking takes place.

"In the autumn they pillage the countryside of everything eatable, from grain gleanings to pepperidge berries and all other edible seeds that would form the winter food of robins and bluebirds. They also gobble the suet and other food put out on winter feeding shelves. At night they either take refuge in buildings or go in cloud-like flocks to the brushed edges of the marsh meadows, these roosts being often discovered by the fact that their droppings have seared the foliage, leaving the bushes leafless. Connecticut has done wisely in placing the starling on the list of unprotected birds, side by side with the English sparrow, but a concerted country-wide effort must be made if the starling is to be kept in check.

"Only a month ago over 500 starlings were captured in the belfry of a nearby country church, by merely placing curtains behind the slat ventilation openings and dropping them after the birds had gone to roost at night, the condition of the tower being something beyond belief.

"If starlings were but few in number, their melodious spring whistle, varied at times with a sort of muttered sound and some very startling ventriloquistic notes, together with the varied seasonal plumage, would make them interesting guests, but as conditions are they are another warning of the foolishness of importing birds to another habitat than their own. Nature resents this meddling and the innocents pay for the mistake of the rash."

THE EUROPEAN STARLING IN INDIANA.

AMOS W. BUTLER, Indianapolis.

In addition to the records of the European starling submitted to this academy at its meeting in 1924 (Vol. 35, p. 325) I herewith present other Indiana records that have been reported to me since that time:

LOWELL. September 13, 1926, seven seen; September 30, five seen; October 10, two; April 17, 1927, one; April 28, two.—Mrs. L. G. Little.

ST. JOE. Several days ago at a "pest" hunt, over 50 strange birds were found at night roosting in the barn of Sam High, four miles west of St. Joe. From the description given I feel that these were starlings.—Sidney R. Esten, December 31, 1926.

LAFAYETTE. January 2, 1927, two were seen one mile south of Lafayette, near the Opp farm. January 4, two starlings were picked up dead in the barn of Mr. Scipio, about six miles south of Lafayette. Mr. Scipio said he had seen as many as 24 at one time. (They probably wintered.) March 9, 1927, two starlings lit in a tree in my back yard in West Lafayette. They were found nesting six miles south of Lafayette, May, 1927. At least one nest with eggs was found.—Prof. L. A. Test.

Dean M. L. Fisher reports starlings nesting at Lafayette in 1927. Possibly the same as last noted.

PENDLETON. One seen with English sparrows, two miles northwest of Pendleton, February 20, 1927. Three building, carrying in shreds of corn fodder, in two flickers' holes, April 5, 1927. May 18, 1927, I went with Mr. Sidney R. Esten to the nest last above mentioned, which was about 25 feet up in a beech snag. It contained six young ready to fly. It is about one and a half miles from Pendleton. I had been keeping watch of the parents since they began building. Mr. Esten preserved the skins of the adult male and one of the young. There were two more adults about the same place but it is not known that they nested. Mr. Esten kindly presented me with two of the young from that brood.—Mrs. W. M. Swain. Mrs. Swain reported, December 6, 1927, about 150 starlings about two miles south of Pendleton, which had been there for the previous two weeks.

ANDERSON. June 8, 1927, I went with Mr. Sidney R. Esten in response to a call from Anderson to see starlings which were reported found there. Went out East Twelfth Street road toward State Road 67. We found six nests occupied by starlings in two hours' observation. All these nests were in holes in telephone poles along the road. The average distance from the ground was 13 feet. We saw eight adult and

one immature starling. Parents were carrying food into three of these nests; the remaining three each had an adult head thrust from it.—Mrs. W. M. Swain.

ANDERSON. June 5, 1927. Today we discovered three nests of starlings in telephone poles between here and Chesterfield, about four miles east. Two nests were near the Poor Asylum, and one near the Tuberculosis Hospital. In two nests the young were just ready to leave. I saw six grown birds and two or three young.—Mrs. H. P. Cook.

HUNTINGTON. In a letter dated May 31, 1927, Mrs. H. P. Cook tells of just having returned from a trip on which she saw, near Huntington, a starling.

MUNCIE. February 12, 1927, saw eight starlings near Muncie. Their peculiar whistling songs and short tails identified them. I was fortunate enough to hear at least one of their number imitate a wood pewee, which imitation Doctor Chapman refers to in his "Handbook." May 29, 1927, Mr. W. W. Tuttle and I found starlings in the same place, probably the same flock, apparently nesting in the top of the dead trunk of a sycamore. The holes were 75 or 100 feet above the ground, so a close inspection was impossible. I am satisfied they were nesting.—Harold A. Zimmerman.

SPICELAND. One was found near here by one of the school girls. It was identified as a starling.—Mrs. Amanda C. Smith.

FORT WAYNE. February 27, 1927, a male starling was brought to me which was taken a short distance from Fort Wayne.—C. A. Stockbridge.

One caught in a barn on a farm March 4, 1927. It was alive and in good condition and will be mounted for Concordia College Museum.—A. A. Ringwalt.

NOTRE DAME. Two observed May 30, 1927. Seven other records in June as follows: One, 7; one, 11; one, 19; one, 23; one, young, 26. First nesting record June 7; one nest in a woodpecker's hole in a telephone pole. August records as follows: three, 10; six, 17; one, 19; one, 24; two, 27; one, 28; one, 29. September, one, 11.—Brother Alphonsus.

MAYWOOD. Miss Rousseau McClellan reported a starling seen at Maywood, March 4, 1927.—S. E. Perkins III.

FOUNTAIN CITY. Elmer Barnes, a former student of Earlham College, found one dead near the above town in April, 1927. The skin is preserved in the Earlham College collection.—Prof. Millard S. Markle.

BROOKVILLE. May 15, 1927, a starling was found dead in the barn by Mrs. May Rodgers on the farm of her brother, Harry M. Stoops, and herself. The only one observed there.—Dr. C. E. Case. The bird is now in my collection.

HANOVER. Mr. S. E. Perkins III has a report from Mrs. Ida Smith, Hanover, of one killed there, November 21, 1926. Only one seen. She sent the mounted specimen to Mr. Perkins for verification.

Through the kindness of Prof. Will Scott, I have a letter from D. O. Alter, Rushville, Indiana, saying a pair of starlings nested in East Hill Cemetery, that city, in 1922, 1923 and 1924, but none have been reported since. Mr. Alter says he did not verify the above reports.

The following two correspondents have reported records from other states, which I am including herein:

JOLIET, ILLINOIS. December 23, 1926, a starling was killed here. It is preserved in Joliet Township High School Museum.—G. N. Hufford.

SANDUSKY, OHIO. Two starlings were noted March 6, 1927. Next recorded March 15, 1927.—Miss Helen Barker.

The record concerning the starling in Indiana may be briefly summarized as follows:

It is rapidly increasing in numbers. It is occupying the nesting sites of other birds. It associates with English sparrows and grackles. It is willing to nest near habitations and along main highways.

Several of the birds recorded have been found dead. Does that mean they die from disease?

In our state it has been found only in the northeastern half of the state. A line drawn from Lake County to Jefferson County shows that practically all the localities are northeast of that line.

It has been reported from 16 counties and found nesting in four counties.

Specimens are preserved for verification from seven localities.

Lack of observers in the southwestern part of the state probably accounts for our not having it reported from that territory. In fact, with more observers throughout the entire state we should probably know much more of it than we now do.

Now we do not look upon the starling as much of a problem. Perhaps in 20 years we shall look upon it otherwise.

SOME INTERESTING INDIANA BIRD RECORDS.

AMOS W. BUTLER, Indianapolis.

I desire to bring to your attention some records of Indiana birds that are of special interest. Unless otherwise indicated they are notes taken in Indiana in 1927.

Snowy owl. *Nyctea nyctea* (Linn.). The extensive flight of snowy owls into Canada, New England and the lake region the past winter also reached Indiana. But the birds did not appear in such numbers as they did farther east.

A photograph in the Indianapolis News, Jan. 12, 1927, of one of these birds killed two miles northeast of Indianapolis first attracted

attention. The same paper, January 19, mentioned one from Frankfort.

Charles A. Stockbridge, Fort Wayne, says two were taken near Columbia City, in Nov., 1926, both of which were brought to him. He also reports one taken about six miles north of Fort Wayne, which is in his collection.

A. A. Ringwalt, Fort Wayne, reports that about a week before Christmas (Dec. 1926), Venus Yoder brought a snowy owl to him. It had been shot about one mile east of Topeka, Lagrange County.

H. A. Link, observed one of these birds at Waterloo Dec 3, 1926.

Professor G. Eifrig says several snowy owls were seen and shot near Gary in December, 1926.

George R. Fox, Three Oaks, Michigan, wrote me on Feb. 28, 1927: The snowy owl was common here this winter. I know of six of them having been killed and several more seen.

Hal H. Coffel, Pennville, reports the following seven snowy owls: Nov. 16, 1926, one taken by Arthur W. Haffner, six miles southeast of Pennville; shot while eating a chicken. One shot by Bert Judy three miles northwest of Bryant, Jay County, March 26. James D. Harrison found one crippled Nov. 22, 1926, on the Straley farm, Jackson Township, Jay County. He took it home, caged it and the wing healed. Later it escaped, was about the woods some three weeks, and then disappeared. One taken, Columbia City, Dec. 11, 1926. One taken 15 miles northeast of Ft. Wayne, Dec. 18, 1926. One taken near Odin, Mich. The three last above were mounted by John Miller of Ft. Wayne.

Nov. 25, 1926, one was reported to Mr. Coffel by C. L. Beasley between Pennville and Montpelier.

Mrs. L. G. Little, Lowell, reported two from that station Jan. 1, 1927, one of which was mounted.

Donald H. Boyd, Hobart, says snowy owls have been very abundant along the edge of Lake Michigan this winter. On December 8, 1926, one was shot from the roof of one of the buildings of the refinery of the Standard Oil Company at Whiting, where it was reported to have been seen for several days previously. The following day another snowy owl was seen perched upon the same roof. He also says a Hammond taxidermist reported he had received nine of these birds between Dec. 1 and 8, 1926.

According to Chreswell J. Hunt of Chicago, two were shot near Gary the first part of December, 1926, (W. Pierce Brodkorb).

I have enumerated 34 definite records, 27 of them from Indiana.

Goshawk. *Astur atricapillus* (Wils.). Another northern bird that appeared in unusual numbers farther east and north was the goshawk. Only a few of them evidently were seen by Indiana observers.

W. Pierce Brodkorb, Chicago, Ill., reports one seen by him Dec. 21, 1926, at Dune Park. He adds: "It was too quick to shoot."

H. A. Link, Waterloo, noted it Dec. 6 and 16, 1926. Quite common all the month of December. Several were seen in January, 1927. The last one on Jan. 26. He also reports one Feb. 19, 1926.

Arctic three-toed woodpecker. *Picoides arcticus* (Sw.). This is another northern bird that has been recorded from this state only

within the past few years. Through the kindness of S. C. Sims, curator of the N. W. Harris Public School Extension Collection of the Field Museum of Chicago, I have been supplied with a number of interesting Indiana records. Among them are three from specimens in that collection as follows: No. 1421 male, Dune Park, Ind., Oct. 3, 1920; No. 1431 male, Dune Park, Ind., Oct. 24, 1920; No. 1121 male, Miller's, Ind., Mar. 11, 1917. All were collected by H. L. Stoddard. The last mentioned is labeled, by mistake, black-backed three-toed woodpecker, but I am informed they are all the same species.

Mr. Brodkorb has a more recent record of three of these birds: one from Oak Hill, Porter County by Mrs. Lillian Cramp, Oct. 24, 1924; and from Miller's, Lake County, Dec. 28, 1924, by Clarence Jung. Feb. 20, 1927, Mrs. W. D. Richardson saw a male arctic three-toed woodpecker at work on a tree in the sand dunes.

Long-tailed jaeger. *Stercorarius longicaudus* Vieillot. A male of this species was taken by H. L. Stoddard at Dune Park, Sept. 21, 1915. It is now No. 205 in the Harris Collection of the Field Museum, Chicago.

A jaeger (species not determined) was seen between Dune Park and Mineral Springs, Porter County, by B. T. Gault, Prof. G. Eifrig and C. J. Hunt, Mar. 17, 1923, according to Mr. Brodkorb.

Yellow-crowned night heron. *Nyctanassa violacea* (Linn.). A female was taken April 3, 1921, at Snider, by E. J. Scupham. It is now No. 1436 in the Harris Collection in the Field Museum.

Prof. G. Eifrig reports a bird of this species which he verified in the Field Museum taken Apr. 21, 1921, in Indiana a little east of the Illinois line near Illinois, Ill., on the Kankakee River.

Alden H. Hadley found one of these night herons dead in the road near Monrovia, in May, 1924. S. E. Perkins III has a photograph of it.

Black-crowned night heron. *Nycticorax nycticorax naevius* (Boddaert). On July 7, 1927, Harold A. Zimmerman and Prof. O. B. Christy of Muncie, located the nesting place of these birds. For weeks small groups had been seen by interested persons. Their "heronry" was found in a grove of boxelder trees along Buck Creek, near Yorktown, about seven miles southwest from Muncie. Seventy-five nests were counted and the number of old birds estimated as 150.

Snowy plover. *Pagolla wilsonia wilsonia* (Ord). Charles Brandler took a female snowy plover at Miller's, on the lake shore, Sept. 4, 1887. It is in the Harris Collection in the Field Museum, No. 1295. Mr. Sims states: Dr. Helmayr, of that Museum, says this is the third record for the Great Lakes Region.

Roseate tern. *Sterna dougalli* Montague. A male of this species was collected by H. L. Stoddard at Miller's, Aug. 14, 1916. It is in the Harris Collection, Field Museum, and is numbered 289. This is the first verified record of this bird for the state.

Caspian tern. *Sterna caspia* Pallas. Formerly considered rare in Indiana. Now not so regarded along Lake Michigan. Dr. Alfred Lewy, according to Mr. Brodkorb, saw a Caspian tern Sept. 25, 1926, in the Dunes.

Mr. Sims, curator of the Harris Collection, Field Museum, has supplied me with the following records from their collection. All were taken by H. L. Stoddard as follows: 102, male, Miller's, Ind., Aug. 30, 1914; 253, female, Miller's, Ind., Aug. 30, 1914; 254, female, Mineral Springs, Ind., Sept. 4, 1915.

Aug. 30, 1919, Prof. G. Eifrig reported it from Miller's. He said he saw several.

Harris' sparrow. *Zonotrichia querula* (Nutt.). These sparrows are apparently extending their range eastward. Some years ago they were regarded as ranging more to the westward. The first Indiana specimen was taken by Ernest P. Walker at Sheridan, May 4, 1907. May 12, 1924, one was recorded from McMillan, Luce County, Michigan (O. M. Bryans) (The Auk, Vol. XLII, January, 1925, page 145.).

May 12, 1924, Ben J. Blincoe reported one from Dayton, Ohio. Oct. 12, 1924, another specimen was secured in the same locality. That appears to be the third Ohio record.

H. L. Stoddard secured an immature female at Miller's, Oct. 3, 1920, No. 1420 Harris Collection, Field Museum.

Mrs. Percival B. Coffin identified one May 12, 1925, at The Brooks, Williamsburg, Wayne County. Other records were made May 14, 15 and 16, 1925, at the same place. Mr. and Mrs. Coffin had twice seen this species in the Indiana Dunes.

Clarence Bretsch, Gary, reports having banded several Harris sparrows in 1926 and 1927. One of these birds, a female, taken May 20, 1927, he presented to Prof. Eifrig, Oak Park, Ill.

Clay-colored sparrow. *Spizella pallida* (Sw.). One of these sparrows was taken at Dune Park, by Chreswell J. Hunt, May 11, 1924. H. L. Stoddard took a female at Dune Park, May 25, 1919. It is No. 1332 Harris Collection, Field Museum. Clarence Bretsch, Gary, reports them abundant in Lake County, the fall of 1926.

Nelson's sparrow. *Passerherbulus caudacutus nelsoni* (Allen). This sparrow was named for E. W. Nelson, who discovered it near Chicago in 1874. It has only been recognized in Indiana a few times. The Harris Collection has two females taken by E. J. Scupham at Long Lake in the Dunes: one, No. 1578, Sept. 12, 1922; and No. 1583, Sept. 21, 1922.

Northern pileated woodpecker. *Phloeotomus pileatus albicincta* (Bangs). This large woodpecker was once well known throughout all the wooded area of Indiana. A few years ago it was regarded as almost extinct with us. However several reports of its occurrence having recently been received it has been thought wise to inquire in some detail into its present distribution.

It is given by Philip Baker, Helmsburg, as a regular, though rare, resident of Brown County. He writes, "I heard one yesterday (Aug. 22, 1927), in the wood just south of mine, and have heard the call or seen the bird many times this year. It must nest in this county as I have often seen them in pairs."

J. Fred Masters of Indianapolis, according to S. E. Perkins III, reported Apr. 3, 1927, four of them on his farm in the northeastern part of the same county.

W. S. Chansler of Mitchell, reported one about Oct. 20, 1926. In 1927 he notes: First seen Feb. 7, one; next, Feb. 8; next, May 20. Rare, breeds. Three pairs "use" in this vicinity.

A. F. Bently, Paoli, writes: The pileated woodpecker seems to be becoming more common. Reported from three localities this year (1927). It has been here in summer for a number of years. This year three were seen at one time. It was here in 1921 and 1922, also May 12, 1923, and April 20, 1926.

Dr. Will Scott, of Indiana University, reports one there January 28, 1926. The same observer saw one, a male, three miles east of Shoals, May 12, 1927, also a pair seven miles east of Bloomington.

Roy Chansler, Bicknell, says he saw two there in 1924, and one in 1925. These reports with the exception of Knox County, are from a group of neighboring counties—Brown, Monroe, Lawrence, Orange and Martin. Probably other counties with similar topography and forests may also shelter some of them. Mr. Brodkorb records one in the collection of J. Grafton Parker, Jr., now in the Field Museum. An adult taken at Kouts, Porter County, December 5, 1894. (The Auk, April, 1927, page 260.)

S. E. Perkins III reports one in the Shortridge High School collection, Indianapolis, taken at Morgantown, Nov. 29, 1925.

Wood ibis. *Mycteria americana* Linn. Mr. Hal H. Coffel reports wood ibises in the vicinity of Pennville, in the fall of 1925. On Aug. 15, 1925, and for two or three weeks thereafter, almost daily; nine of these ibises were seen by C. V. Edmundson in a pond on his farm four miles northeast of Pennville. The owner thought they were feeding upon the fish in the pond. Sept. 1, 1925, five were seen.

On the Gladys Hamlin farm, somewhat more than a mile northeast of Pennville, two of these birds were found hanging on a wire fence. Mr. Coffel went to see them and identify them. They had been hanging there for some time and were not in condition for preservation. Sept. 6, 1925, he saw two wood ibises one mile northwest of Pennville along the Salamonie River. They were soaring high above the river. One came down to the water at some distance from him and when it flew away it had something in its bill, presumably a fish.

Black vulture. *Catharista urubu* (Vieill.). Mr. McKim Copeland informs me that the black vulture wintered in considerable numbers in southern Indiana last winter. Some 150 made their winter quarters among the rocks of Clifty Ravine in the State Park. It is locally found in some numbers and breeding as far north as the B. & O. Railroad.

W. S. Chansler reports them as common and breeding in Lawrence County.

Prothonotary warbler. *Protonotaria citrea* (Bodd.). When this Academy was organized the prothonotary warbler was practically unknown in Indiana. The lower Wabash and the Kankakee held what little we knew about it. Its verified range now extends over much of the state in suitable localities. It prefers water with willows, cottonwood and other soft woods where there are dead trees and stubs, in the cavities of which it can nest. The following will give some of the records:

Notre Dame. Brother Alphonsus, May 15, 1919, May 27 and 29, also Aug. 25, 1927.

West Lafayette. F. H. and L. A. Test, Apr. 30, 1927, "not common."
Lafayette. Mrs. C. F. Weigle, Apr. 30, 1927.

Dune Park. W. Pierce Brodkorb, May 6, 1923, two seen by Lewy, Swift and Gault.

Bluffton. E. B. Williamson. At least two pairs were found in Vaneman Swamp near Bluffton, June 9, 1927, nesting in abandoned nest of downy woodpecker.

Crawfordsville. Mr. Frank C. Evans and Mrs. B. F. Sarver, May 19, 1927, one seen. Noted two or three times before.

Indianapolis. S. E. Perkins III, two at Bacon's Swamp, Apr. 24, 1927.

Middletown. Reported by Mrs. Rose Pickering. It was previously reported from Newcastle by Clarence H. Smith.

Bloomington. Dr. Will Scott, May 2, 1925; May 7, 1927.

The nesting reports of the prothonotary warbler are of much interest. According to the books, it nests in a natural cavity or excavation, in a tree or stump, often a willow standing in or near water. The experience of S. E. Perkins III, July 14, 1926, in finding a nest with young, on a stringer of an occupied building at the Boy Scouts Camp, some eight miles northeast of Indianapolis, was unique. Along with it came a report of a nest with young discovered by Miss Luci Pitzschler at McCormick's Creek State Park, Owen County, in July, 1926. (The Auk, Oct., 1926, p. 551.) These records recalled to Edw. R. Ford, Grand Rapids, Michigan, an experience he had in company with Frank Morley Woodruff, in June, 1910, near Kouts, Indiana, where "the prothonotary was a common breeding species." One of these birds was found nesting in an empty lard pail hanging beneath the porch of a fisherman's shack along the Kankakee River. (The Auk, Apr., 1927, p. 255.)

Worthington. J. M. Tilley, Superintendent of Schools, in reporting its breeding at that station, says "In 1926 a pair of them built in an empty can in a garbage can on a house boat." Reported also May 10, 1927.

Mrs. C. B. Bowman, Portland, writes, "a friend tells me a prothonotary warbler built its nest in the mail box on the side of the main door to Stony Ridge Hotel at Tippecanoe Lake, and hatched its young."

Dr. L. A. Test says, in 1925 a pair of these birds built their nest in a cavity in one of the piles at the boat house at Winona Lake. It was about 18 inches above the water. In 1927 they nested at the boat house in a pile near the one in which they nested before. The cavity was similar to the one formerly used. They were quite common at Winona Lake during the summer of 1926 but no nest was reported.

Mrs. Elizabeth C. Marmon who has records of this warbler at Lake Maxinkuckee, reports it nested near Mr. Coffin's place in 1911. Mr. Perkins noted one at that lake June 28, 1925.

Mitchell, 1927, Apr. 20, one; Apr. 26; Apr. 30; Tolerably common; breeds.—Walter S. Chansler. Bicknell, Nests along streams.—Roy Chansler. English Lake, The Field Museum has a set of eggs taken at English Lake, June 30, 1907 (Chas. B. Cory).

Cliff swallow; eave swallow. *Petrochelidon lunifrons* (Say). In recent years we have had to change our books regarding this swallow. Formerly it was an abundant migrant and summer resident. Now in many localities it is unknown. Few breed with us. What is their future?

The following records are here made: Roy Chansler, Bicknell, Apr. 10, 1927. Nests locally.

Walter S. Chansler, Mitchell, 1927. May 8, one; May 12; May 17. Common, breeds. Mr. Chansler writes "about four years ago (1923) while cruising the lower Wabash River I observed these birds in colonies along the rock bluffs at various points on both sides of the river."

H. A. Link, Waterloo. Last nested here in 1915, when two pairs built nests. He also adds, "Aug. 20, 1925, saw ten at Wall Lake, La-grange County."

Brother Alphonsus says they are regularly found and fairly abundant at Notre Dame.

One noted at Anderson, June 1, 1926. Mrs. H. P. Cook, Lafontaine. Tolerably common. Three May 11, 1927. A pair nested in a barn near Rochester, the summer of 1924.

Dr. Will Scott records them twice at Bloomington in 1925, May 2 and 9.

O. A. Renahan, Wawaka, writes: I saw some eave swallows last year (1926) but have no record of their nesting. Some 12 or 15 years ago an old barn about a mile from home held some 50 nests of eave swallows. Between nearly every two rafters there were three nests. It certainly was great to go there about the time the birds were hatching and feeding. It was like a hive of bees. One could drive right up to them in a buggy. They were too busy to notice the visitor. The colony of birds had been there for years. The roof on this old barn was getting very leaky. Then came a very rainy season at the time the young were hatching. The rain leaked through the roof, wetting the nests which loosened and fell to the ground. The owner, who was fond of the birds, gathered a grape basket full of young swallows, all sizes. It was a sad sight. We selected a few of the older ones and succeeded in raising two of them. The next year there was one nest under our home barn-roof and two others started but not completed. The swallows never returned to nest at the old barn. Some years later a small colony of these swallows nested at our tenant's barn but do not think they nested there last year.

Eave swallows were seen in the Dunes at Fremont, May 30, 1924, by G. P. Lewes, who adds: "getting rare here."—Brodkorb.

A colony of these birds was found by Dr. L. A. Test, at West Lafayette, in May, 1927, nesting under the eaves of a barn on the farm of Mr. Scipio, six miles south of West Lafayette. There were about 30 nests in the colony, some still in the process of construction, and all under the eaves on the north side of the barn. This is the first time, at least for some years, that these birds have nested there. This is the largest colony of these swallows known to me in the state. It is of interest to note that barn swallows were nesting inside the barn.

Mocking bird. *Mimus polyglottos* (Linn.). In contrast with the history of the cliff or eave swallow, the mockingbird appears to be increasing its numbers and extending its range in Indiana. Forty years ago one could expect to find it in suitable localities in the southern third of the state, say to the line of the Baltimore and Ohio Railroad, and nesting practically throughout that area. More recently we have learned of their nesting as far north as the latitude of Indianapolis. Now we may expect to find them irregularly throughout the state.

Dr. C. W. Hargitt reported them as common residents in Dearborn County on July 2, 1906.

Philip Baker reported several birds and one nest just southwest of Indianapolis, June 24, 1907.

Robert A. Wilkes, Nineveh, reports them six miles west of Edinburg, in 1911. They bred there for the preceding three years. They came with the robins in 1911.

Mrs. Emma L. Dennis informs me that one wintered at Richmond, 1921-22. Have been seen quite a number of times in recent years. Both Mrs. Dennis and Prof. Millard S. Markle informed me of their nesting in the hedge between Earlham College and the cemetery this year. There were three eggs. One was broken and the birds abandoned the nest. June 1, 1927.

Prof. J. M. Tilley, April 23, 1927, notes they are common and breed at Worthington. It is reported from Washington, common, breeds. Some dates given in 1927, Jan. 6, Feb. 14, Mar. 13 and 23, Apr. 8.

At Bicknell, Roy Chansler says: Usually resident. Tolerably common; breeds.

Wintered at Mitchell in 1926-27. Some dates for 1927. Jan. 20; Feb. 15; Apr. 15. Common; breeds. Walter S. Chansler.

Mrs. C. B. Bowman, Portland, reports it there Oct. 21, 1925, and adds: It nested there in 1914 and 1915.

The following additional records are given as showing, with those above, a sketch of the recent distribution of mocking birds in Indiana:

Evansville, Feb. 25, 1926; Apr. 10 and 12, 1927. Dr. A. J. Bigney.

Bloomington, Feb. 15 and Mar. 19, 1921; Apr. 15, 1922; Feb. 13 and May 9, 1925; Feb. 5 and Apr. 24, 1926; Feb. 5 and May 7, 1927—Dr. Will Scott.

Helmsburg, Brown County. March 27, 1922. Philip Baker.

Morgantown, May 30, and June 15, 1927. Seen by me in company with Mr. Perkins.

Hope, May 11 and 16, 1927. Common. J. K. Pittman.

Crawfordsville, Spring Ledge. Frank C. Evans reports Mrs. B. T. Sarver's note May 20, 1927. Reported each year but observers have not seen nest.

Fort Wayne, Prof. G. Eifrig wrote me of seeing one near there.

Glen Ellyn, Illinois. B. T. Gault writes, June 13, 1927, it was found at that place this spring.

Chicago, Illinois. One seen for some time, Nov. 28, 1926, at the Bird Sanctuary, Lincoln Park, by S. E. Perkins III, and several other persons attending the joint meeting of the Inland Bird Banding Association and the Wilson Ornithological Club.

Notre Dame, Nov. 23, 1927. Brother Alphonsus.

From Evansville to Lake Michigan and from Aurora to Fort Wayne, we have recent records. These records, especially in its northern range, are variable. Sometimes for two or more years a site will be occupied for nesting, then the birds may not be seen for years, or may not be found again.

NESTING OF THE SYCAMORE WARBLER.

AMOS W. BUTLER, Indianapolis.

While the sycamore warbler (*Dendroica dominica albilora* Ridgway) is a common summer resident, few there are who know it and fewer still who have found and recognized its nest. Mrs. Harry Bucklin, of Brazil, is indeed fortunate in her knowledge of and acquaintance with this bird. In her collection I found last summer the first sycamore warbler's nest I ever saw. In conversation I learned she knew the haunts of these birds and for several years past had observed their nests. After the season was over, on two occasions she was able to secure the nest. One of these (A) she has; the other (B) she kindly presented to me. Both nests were taken at Pennyroyal, Clay County, Indiana, the summer home of Mr. and Mrs. Bucklin. Both nests were built in the same sycamore tree but three years apart.

Nest "A" was built about 35 or 40 feet above the ground in a flat crotch, on an approximately horizontal limb of a large sycamore tree. The birds were seen building on April 26, 1924, but they are usually seen first about the middle of April. One date is April 16. The nest measures as follows: Outside diameter, 2.50 inches; inside diameter, 1.65; outside height, 2 inches; inside depth, 1.75 inches.

The heavier frame was composed of shreds of grapevine bark, bits of the covering and coarser fibre of weeds, mingled with which were many small pieces of cotton cord or ravelings. The nest was lined and its entire bottom was composed of the soft down obtained from dry sycamore balls. In fact, the nest really had no foundation for the bottom. The lining material reached through to the limb. The nest was taken after the young had left.

Nest "B" was built about May 14. The birds were first seen April 17, 1927. The nest was about 75 feet above the ground in a crotch of small branches toward the end of a sycamore limb which was not strong enough to bear one's weight. It was so hidden by the foliage that it could not be seen until some of the leaves fell this fall. Then it was secured but was mashed against another limb so that its measurements doubtless are only approximately correct.

The nest is composed of weed and other vegetable fibres, including the shredded bark of grape-vine and a few horse hairs. It was lined with down from plants, including that from the ripened sycamore balls.

The bottom of the nest was cushioned entirely by the latter. Measurements (approximate): outside diameter, 3 inches; inside diameter, 1.50 inches; height, outside 2.75 inches; inside depth, 1.45 inches.

The sycamore warbler is well named. It is partial to sycamore groves. It frequents the sycamore trees along streams, especially their smaller tributaries. Its food is largely obtained from the sycamore. In a sycamore it builds its nest and lines it with the down from the last year's sycamore balls.

A LIST OF REPTILES AND AMPHIBIANS TAKEN IN
MARION COUNTY, INDIANA, IN 1924-1927.

STEWART SPRINGER, Butler University.

The following list is made from the specimens in the writer's collection taken in Marion County. It is therefore probably incomplete as no very intensive collecting has been done except at Bacon's Swamp.¹ Owing to the extremely populated condition of the county it is probable that some species have been driven out in the last few years but even so the list shows a greater number of species than would be expected in and about a large city. The snakes have suffered from the increasing population more than the other forms. The larger species of snakes are quite uncommon but the garter snakes seem to be in no way decreasing in number. They are rather increasing.

In addition to the species listed the red-bellied snake, *Storeria occipitomaculata* (Storer), has been found in Irvington;² the keeled green snake *Ophedrys aestivus* (Linn.), and the smooth green snake, *Liopeltis vernalis* (Harlan), have both been found by Miss Rousseau McClellan of Shortridge High School; and the mud turtle, *Kinosternon subrubrum* (Lacepede),³ probably occurs.

Plethodon cinereus (Green), *P. dorsalis* (Cope), *P. glutinosus* (Green), *Eurycea bislineata bislineata* (Green), and *E. longicauda* (Green) were all taken in the southwest corner of Marion County. They are particularly abundant in Morgan County. All of these species were found together in the shales at Sycamore Creek near Centerton in Morgan County. Dunn records both *Plethodon cinereus* and *P. dorsalis*, which are very closely related, from the same localities in Indiana. At Sycamore Creek *Plethodon dorsalis* is somewhat rare.

1. *Necturus maculosus maculosus* (Rafinesque)—Water Dog.
2. *Ambystoma maculatum* (Shaw)—Spotted salamander.
3. *A. tigrinum* (Green)—Tiger salamander.
4. *A. microstomum* Cope—Small mouthed salamander.
5. *A. jeffersonianum* (Green)—Jefferson's salamander.
6. *Triturus viridescens* (Rafinesque)—Crimson spotted newt.
7. *Eurycea bislineata bislineata* (Green)—Two-lined salamander.
8. *E. longicauda* (Green)—Long-tailed salamander.
9. *Plethodon glutinosus* (Green)—Slimy salamander.
10. *P. cinereus* (Green)—Red backed salamander.

¹ Cain, Stanley A. Airplane Photography and Ecological Mapping. Proc. Ind. Acad. Sci., vol. 36, (1927), p. 269.

² Hay, O. P. Batrachians and Reptiles of Indiana, 17th Ann. Rep. Ind. Geol., 1891, p. 498.

³ Myers, G. S. Synopsis for Identification of Amphibians and Reptiles of Indiana. Proc. Ind. Acad. Sci., vol. 35, 1925 (1926), p. 293.

"Proc. Ind. Acad. Sci., vol. 37, 1927 (1928)."

11. *P. dorsalis* (Green)—Red backed salamander.
12. *Bufo americanus* Holbrook—American toad.
13. *Acris gryllus* (Le Conte)—Cricket frog.
14. *Pseudacris triseriata* Wied—Swamp cricket frog.
15. *Hyla crucifer* Wied—Spring peeper.
16. *H. versicolor versicolor* (Le Conte)—Gray tree frog.
17. *Rana pipiens* Shreber—Leopard frog.
18. *R. clamitans* Latrielle—Green frog.
19. *R. catesbeiana* Shaw—Bull frog.
20. *Sceloporus undulatus* (Latrielle)—Common swift.
21. *Eumeces fasciatus* (Linn.)—Blue-tailed skink or redhead.
22. *Heterodon contortrix* (Linn.)—Hog-nosed snake.
23. *Storeria dekayi* (Holbrook)—Brown snake.
24. *Elaphe obsoleta obsoleta* (Say)—Pilot black snake.
25. *Natrix kirtlandii* (Kennicott)—Kirtland's snake.
26. *Natrix sipedon sipedon* (Linn.)—Common water snake.
27. *Thamnophis radix butleri* (Cope)—Butler's garter snake.
28. *T. sirtalis sirtalis* (Linn.)—Common garter snake.
29. *Diadophis punctatus edwardsii* (Merrem)—Ring necked snake.
30. *Coluber constrictor flaviventris* (Say)—Blue racer.
31. *Lampropeltis triangulum triangulum* (Lacepede)—Milk snake.
32. *Amyda spinifera* (Le Sueur)—Soft shelled turtle.
33. *Chelydra serpentina* (Linn.)—Snapping turtle.
34. *Sternotherus odoratus* (Latrielle)—Musk turtle.
35. *Graptemys geographica* (Le Sueur)—Geographic turtle.
36. *Chrysemmys marginata marginata* (Agassiz)—Painted turtle.
37. *Clemmys guttata* (Schneider)—Spotted turtle.
38. *Terrapene carolina carolina* (Linn.)—Carolina box turtle.

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⁴Figures following M, F, and NR indicate date of election to membership, fellowship and non-resident fellowship respectively.

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*Christy, O. B., Ball Teachers' College, Muncie.....	M19, F26
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Cook, Rolla Vergil, Bethany, West Virginia.....	M21
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Coopridger, J. L., Central High School, Evansville.....	M26
Copeland, Joseph J., Paoli.....	M26
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†Coulter, John M., Boyce Thompson Institute, Yonkers, N. Y.....	NR08
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Crouch, Frances E., Hanover.....	M27
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Cummins, John A., Indiana Central College, Indianapolis.....	M23
Cummins, Miss Margaret, Bloomington.....	M27
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Danglade, Ernest, Vevay.....	M20
Darnell, Warren E., 102 S. Neal, Indianapolis.....	M27
†Davis, B. M., University of Michigan, Ann Arbor, Michigan.....	NR16
Davis, Edna E., 101 Fairfield Ave., Brookville.....	M23
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*Davis, John J., Purdue Univ., W. Lafayette.....	M20, F24
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*Deam, Charles C., Bluffton.....	M00, F10
Dean, John C., University Club, Indianapolis.....	M14
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*Dietz, Harry F., State House, Indianapolis	M69, F22
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Doan, Martha, Baker Lab. Cornell Univ., Ithaca, N. Y.	M96
Doan, Richard L., Reed College, Portland, Oregon	M22
Dolan, Joseph P., Syracuse	M95
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Garregies, John Paul, Brazil	M26
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Harmon, Daniel L., St. Mary's-of-the-Woods	M25
Harmon, Jesse, Lexington	M27
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Headlee, W. Hugh, Morristown	M26
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Heiser, Joseph Alan, Notre Dame University, Notre Dame	M27
Helman, Howard H., 15 N. Benton St., Peru	M27
Hendricks, Jesse C., 1126 N. Broadway, Greensburg	M24
Hendricks, Victor K., 491 N. Lombard Ave., Oak Park, Ill.	M00
Hennel, Cora B., 822 Atwater Ave., Bloomington	M25
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Hershman, J. Bernard, 395 Monroe, Valparaiso	M26
*Hess, Walter N., DePauw University, Greencastle	M17, F23
*Hessler, Robert, 25 S. Bolton St., Indianapolis	MCharter, F99
Hiatt, Lee Atta, 233 E. Arch St., Portland	M26
Higgins, Frank R., 1719 N. 9th, Terre Haute	M25
Higgins, Nash, Crawfordsville	M24
Hile, Ralph O., 4017 Bowman Ave., Indianapolis	M26
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Hills, Donald C., 625 Udell St., Indianapolis	M22
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Hoffman, Ira C., 445 Vine St., W. Lafayette	M24
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Holl, Dr. Carl Waldo, North Manchester	M26
Hooper, Florence, Iowa State College, Ames, Iowa	M24
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Hoskins, John Hobart, Univ. Cincinnati, Ohio	M27
Howell, L. B., Wabash College, Crawfordsville	M24
Howick, Howard, Ball Teachers College, Muncie	M21
Howlett, Berton A., Physics Dept., I. U., Bloomington	M19
Huber, Leonard L., Hanover Collge, Hanover	M15
Huebotter, Harry A., 326 Fowler Ave., W. Lafayette	M24
Hufferd, Ralph, Greencastle	M20
Hufford, Francis G., 965 River St., Batavia, Illinois	M24
Hufford, Gayle N., 216 Seeser St., Joliet, Illinois	M26
*Hufford, Mason E., 514 S. Sluss Ave., Bloomington	M14, F16
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Hutchinson, Emory, Norman Station	M25
Hutton, Joseph G., State College, Brookings, S. D.	M11
Hyatt, George F., 140 W. Sheridan St., Greensburg	M25
Hyslop, George H., 116 E. 63rd St., New York City, N. Y.	M14
Inskeep, Anna M., Monticello	M24
Irons, Vernal, Jasonville	M
Irving, Thomas P., Univ. of Notre Dame, Notre Dame	M14
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Jackson, Jas. Wm., Central H. S., Chattanooga, Tenn.	M18
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Jensen, Howard E., Univ. Missouri, Columbia, Mo.	M21
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Kaley, Leona M., Bremen	M23
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Kaylor, J. F., Dept. Conservation Div. Forestry, Indianapolis	M27
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Kellogg, Mary, Boswell	M23
Kelly, E. Lowell, R. R. 3, Russiaville	M26
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*Kern, Frank D., State College, Pa.	M05, F12

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Kinnet, Russell, Milroy.....	M23
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Lahr, John Paul, Y. M. C. A., Indianapolis.....	M27
Lambertson, Margot G., Moores Hill.....	M27
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Leamon, Grace, Stockwell.....	M24
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Liston, Jesse G., R. R. 2, Lewis.....	M16
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Loughridge, Gasper Arthur, Fillmore, Illinois.....	M23
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McDonald, Clinton C., Univ. of Wichita, Wichita, Kansas.....	M22
McEachron, Karl B., 23 Waverley St., Pittsfield, Mass.....	M21
McKeon, Frederick T., Notre Dame.....	M27
McMahon, Frances G., 277 Littleton, W. Lafayette.....	M24
McWilliams, Thelma, 126 Lutz Ave., W. Lafayette.....	M23
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Mackell, James F., R. R. A, Terre Haute	M25
†McMullen, Lynn Banks, Northern Ariz. Normal School, Flagstaff, Ariz. .	NR
*Mahin, Edward G., Notre Dame Univ., Notre Dame	M16, F22
*Mains, E. B., 422 Waldron St., W. Lafayette	M16, F25
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*Markle, M. S., 528 National Ave., Richmond	M10, F19
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Marting, Dorsey P., English	M26
Malek, George, Gardner, Illinois	M27
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Miller, Fred A., R. R. 2, Greenfield	M68
†Miller, John Anthony, Swarthmore, Pennsylvania	NR68
Miller, John W., Penn State College, State College, Pa.	M19
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Miller, Virgil H., Greentown	M25
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